A Manual Method for Optimizing Low Energy/Passive Solar Home Designs

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The contents of this document are based on information readily available four months prior to the above date.

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PREFACE

In recent years design for passive solar gains has been seen to provide a low cost means of contributing to space heating in Canadian housing. To assist Canadian builders and designers in providing for effective use of passive solar gains in new housing covered by Part 9 of the National Building Code, the Housing and Urban Development Association of Canada (HUDAC) and the Ontario Ministry of Energy have commissioned this document, prepared by Okins, Leipciger, Cuplinskas, Kaminker and Associates, Consulting Engineers, and the IBI Group.

Previous advice on energy efficiency in new housing sponsored by HUDAC and the Ontario Ministry of Energy has included such publications as the Builders' Guide to Energy Efficiency in New Housing, and Buying Your Energy Efficient New Home. The advice in the present document extends this assistance to builders and designers to give them a greater understanding of the role that can be played by passive solar design features in new housing, and provides a means of computing the contribution of these features to space heating at an acceptable level of accuracy.

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INTRODUCTION

Passive solar gains, using that renewable energy source the sun, can provide a significant contribution towards reducing space heating costs in Canadian homes. The extent of energy reduction in tract housing, with normal amounts of window area, can be in the range of 20-30%. With the trend towards more tightly-built and highly insulated houses, the percent contribution by passive solar gains is increased. It therefore becomes increasingly important for builders and designers to understand the principles and techniques of using passive solar energy so that they can be combined in an optimum manner with other energy conservation features. To be able to do this, it is useful to know how to compute heat loss, heating energy requirements, and extent of temperature swing to avoid excessive solar gain. This manual provides this information in three successively increased levels of detail to guide the selection of an optimum combination of energy-efficient features.

This manual focuses on passive solar systems. It does not discuss systems which use fans or pumps to move solar energy from the point of gain to storage devices and from storage devices to the point of use (this application of mechanical equipment forms the basis for active solar systems). The passive systems discussed herein deal primarily with direct gain, i.e. solar energy entering into rooms.

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The manual is organized in three parts:

- Part One provides an overview of passive solar design features with definitions and examples, identifies other elements of low energy housing design, and discusses criteria for selecting an optimum combination of design features;

- Part Two provides short form heat loss and energy requirements calculations for quick comparison of alternative housing designs; and

- Part Three provides long form heat loss and energy requirements calculations, heat storage capacity calculations (and temperature swing and sizing of thermal mass estimates), effects of shading and effects of off-true-south orientation for more accurate estimates of energy requirements.

Six appendices offer useful related information.

- Appendix A contains climatic information for Ontario by location;

- Appendix B gives R values for a wide range of construction materials;

- Appendix C provides an example of completed short form calculations;

- Appendix D offers an example of completed long form calculations;

- Appendix E gives an example of completed heat storage calculations;

- Appendix F lists publications for further reading for builders and designers.

PART ONE: REVIEW OF PASSIVE SOLAR ENERGY DESIGN FACTORS

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PART ONE: REVIEW OF PASSIVE SOLAR ENERGY DESIGN FACTORS

Part One of the Manual consists of an introduction providing an overview, a detailed discussion of passive solar design factors, and a brief discussion on measures to reduce heat loss through the building's shell and to improve the efficiency of mechanical equipment.

1.1. INTRODUCTION

Part One provides builders and designers with the main terms and principles used in passive solar design. It serves as an introduction to the short form and detailed form calculation procedures provided in Parts Two and Three respectively.

1.1.1 Purpose

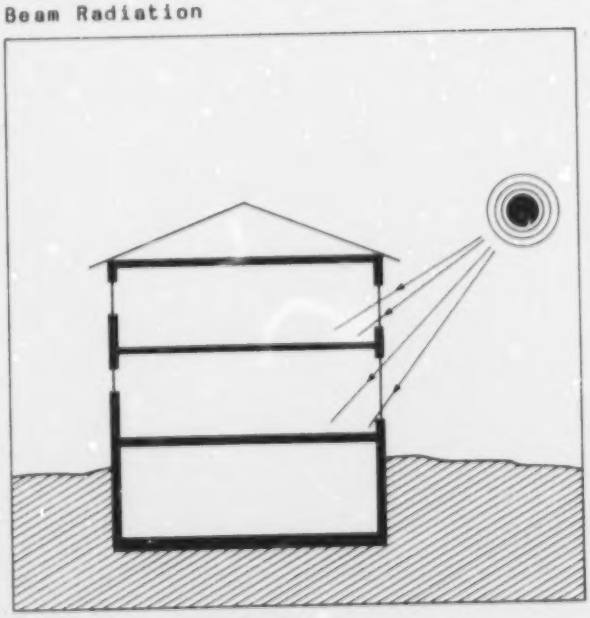
The following notes provide builders and designers with an understanding of the main factors influencing passive solar effectiveness in low-rise housing. This also includes a review of features which can reduce heat loss through the building envelope and a brief discussion on mechanical equipment and appliances which save energy.

1.1.2 The Three Categories of Solar Radiation

Solar energy for space heating can be described in three ways, depending upon how it moves from the sun to the building envelope:

1. Beam Radiation; energy from the sun's rays passing directly from the sun and striking the building envelope (to receive direct beam radiation the building surface must therefore be exposed to direct sunlight). See Figure 1.1.

Figure 1.1
Beam Radiation



2. Sky Diffuse Radiation; that portion of energy from the sun's rays that is diffused by particles in the atmosphere and which then strikes the building envelope (this type of solar energy gain is available to all exposed portions of the building envelope, whatever their orientation). See Figure 1.2.

3. Ground Reflected Radiation; this form of solar gain comes from the sun's rays striking such surfaces as patios, driveways, lawns or pools, permitting radiation to reflect back up against the building envelope. See Figure 1.3.

The most significant of these categories is beam radiation which provides the main source of passive solar gains. Ground reflected radiation can assist solar gain but it must also be considered as a possible source of overheating, particularly in summer.

Figure 1.2
Sky Diffuse Radiation

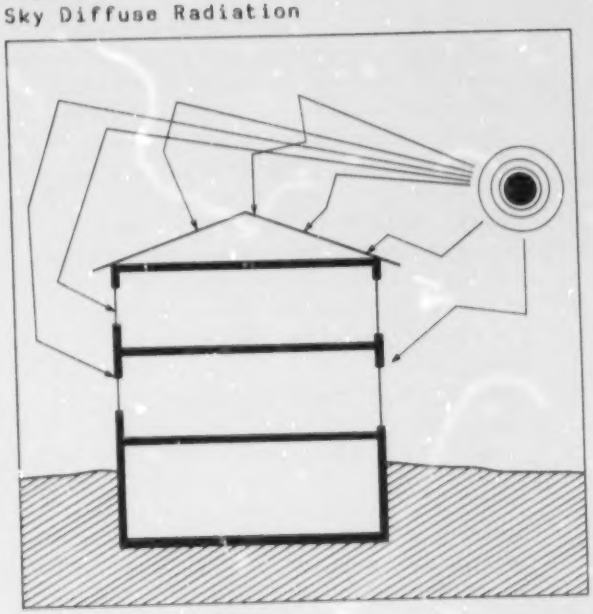
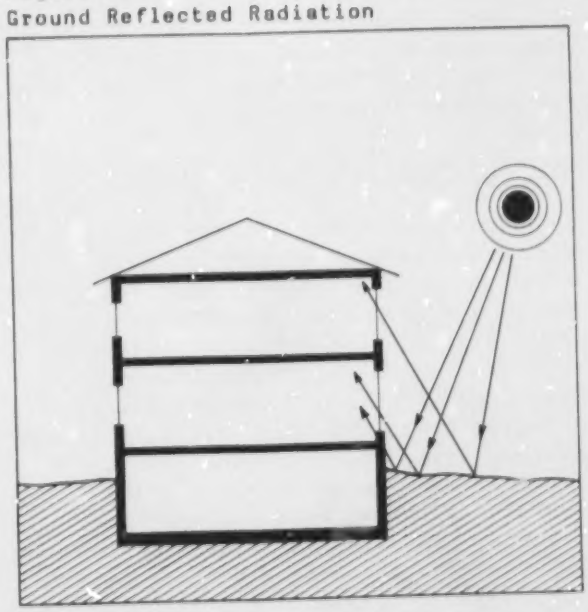


Figure 1.3
Ground Reflected Radiation



1.1.3 Main Factors Affecting Solar Gain

This section of the manual reviews a number of factors that affect solar gain. Awareness of these is important in selecting design and construction features to optimize passive solar gains. These factors include:

1. Geographic Location; the geographic location of the dwelling affects the amount of solar radiation striking vertical surfaces (i.e. on windows) through variations in latitude and the extent of cloud cover. Generally in Ontario, the further north the location, the greater the available solar energy during the heating season because of the lower angle of the sun in northern locations.

2. Orientation and Siting; the placement of the dwelling relative to due south, and with respect to topographic, landscape or nearby building elements can affect the amount of solar energy striking the dwelling envelope.

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3. Glazing; the total window area and placement of windows relative to available solar gain.

4. Shading Effects; the presence of landscape and building elements such as walls and overhangs which prevent solar energy from striking the building envelope.

5. Monthly Solar Gains Utilization Efficiency; the proportion of solar energy passing through the building envelope that can be used to heat the interior during any month. Heavy, dense construction materials (thermal mass) can serve to store solar gain that is not needed immediately for later use at night and on cloudy days, thereby improving monthly solar gains utilization efficiency.

6. Improved Thermal Efficiency of Building Envelope; increased insulation slows down the rate of heat loss. This insulation increase somewhat reduces the amount of solar gain that can actually be used. Increased airtightness has the same effect, also due to the slower rate of heat loss.

The above factors, with the exception of geographic location, can generally be modified by the building designer in a way that can effectively reduce the need for purchased space heating.

1.1.4 Illustrated Examples

To illustrate the effectiveness of the above features in providing passive solar gains, and reducing heat loss, the manual includes a series of examples. These examples are based on variations to a typical builder's house commonly found in southern and central Ontario. Referred to as the "base case", this two storey, three bedroom house has a finished floor area of 124 m^2; it contains a living room, dining room, kitchen, two bathrooms and an unfinished full basement. These and other details are listed in Table 1.1. Plans and elevations are shown in Figure 1.4.

TABLE 1.1

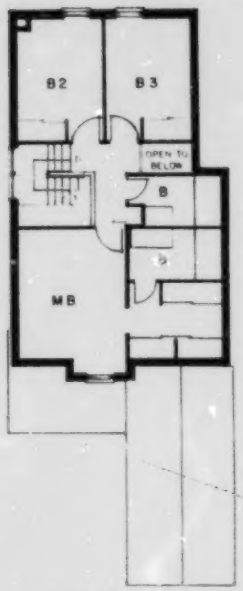
BASE CASE HOUSE

(HUDAC Energy Saver Standards)

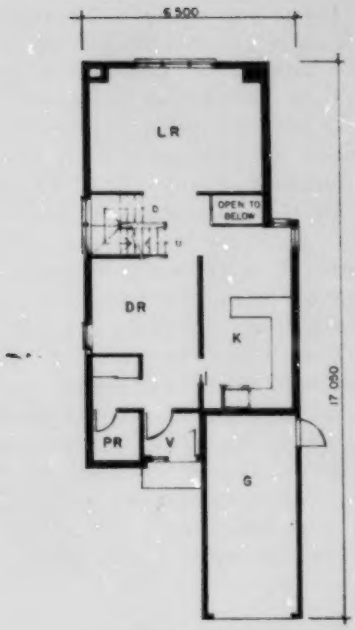
Degree Days C:	4082
Storage Mass:	All light-weight surfaces
Infiltration Rate:	.3 air change/hr.
Forced Ventilation:	0.0 m^3/hr.
Roof R value:	5.52 $m^2°C/W$
Wall R value:	3.14 $m^2°C/W$
Basement R values	
Above Grade:	1.9 $m^2°C/W$
Below Grade:	1.6 $m^2°C/W$
Floor:	0.0 $m^2°C/W$

Wall No.	Window Area	Orientation	Layers of Glazing
1	5.52	S	Double
2	1.48	W	Double
3	2.02	N	Double
4	5.25	E	Double

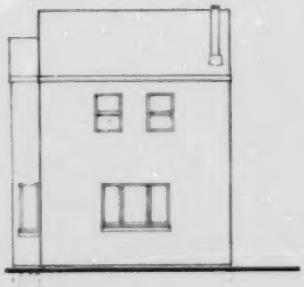
Figure 1.4
Base Case House



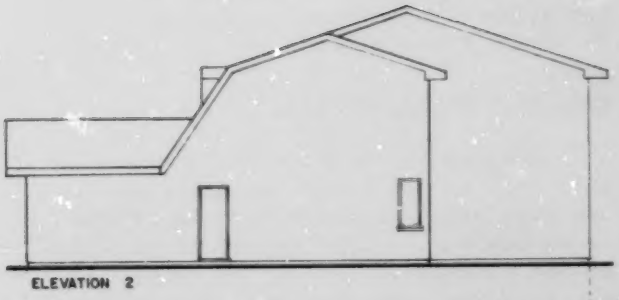
SECOND FLOOR PLAN



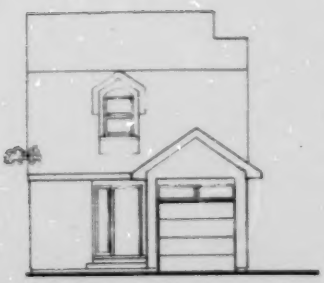
GROUND FLOOR PLAN



ELEVATION 1



ELEVATION 2



ELEVATION 3

ELEVATION 4

Insulation levels shown are typical for the Toronto area and are consistent with the HUDAC Energy Saver Standards of 1981. Note that one of the side walls has significant glazing. Because of shading from adjacent dwellings this glazing is not effective for solar gain even if it faces south. However, because it represents a common solution to providing natural light in a typical merchant builder plan, this feature is included in the base case illustration.

To show the effect on passive solar gain, each of these factors is modified while keeping the others constant (with exceptions as indicated). The usable solar gain and auxiliary space heating requirements are provided for each variation shown as bars and expressed in MJ per heating season (September to May inclusive). The total height of the bar indicates the net heat load after taking into account internal gains from people and appliances.

Designers of passive solar low energy housing should be aware that the combined energy reduction effect of several energy conserving features is usually less than the sum of the individual effects of the features. This is due to the way in which these features interact. The short form and long form calculation procedures in Parts Two and Three are designed to determine these effects.

1.2 GEOGRAPHIC LOCATION

Geographic location has a major influence on passive solar gain, but is one over which the designer has little or no control. It is useful to be aware of the size of its effect in order to maximize the usage of solar energy.

1.2.1 Significance of Geographic Location

Geographic location affects the maximum possible solar gain primarily due to the effect of latitude on the

plan angle of the sun's rays (azimuth) and on the vertical angle of the sun's rays (altitude). In general, the further north the geographic location, the greater the possible amount of low angle winter sun that can strike vertical surfaces such as windows. The prevailing cloud cover reduces this figure for a given location to provide the available amount of solar energy. The Atmospheric Environment Service publishes the available amount of solar energy striking a vertical surface per month at given Canadian locations in MJ. Appendix A provides the solar gains through double glazing for selected Ontario weather station locations.

1.2.2 Example

To illustrate the effect of location, the manual provides energy information for the base case house in Toronto and for a similar house located in Thunder Bay. Consistent with the 1981 HUDAC Energy Saver Standards, the wall and ceiling insulation levels of the Thunder Bay house are upgraded according to the degree day levels of that location (Table 1.2). The increase in solar gains and change in space heating are illustrated in Figure 1.5. Note that the increase in auxiliary space heating is a result of the much higher number of C degree days in Thunder Bay (5746) as compared to the number for Toronto (4082), which is not totally offset by the increase in Thunder Bay passive solar gains.

1.3 ORIENTATION AND SITING

Designers and builders can have considerable influence in selecting the orientation and siting of houses. These factors can be used to increase passive solar gains often at little or no increase in the cost of the house.

1.3.1 Significance of Orientation and Siting

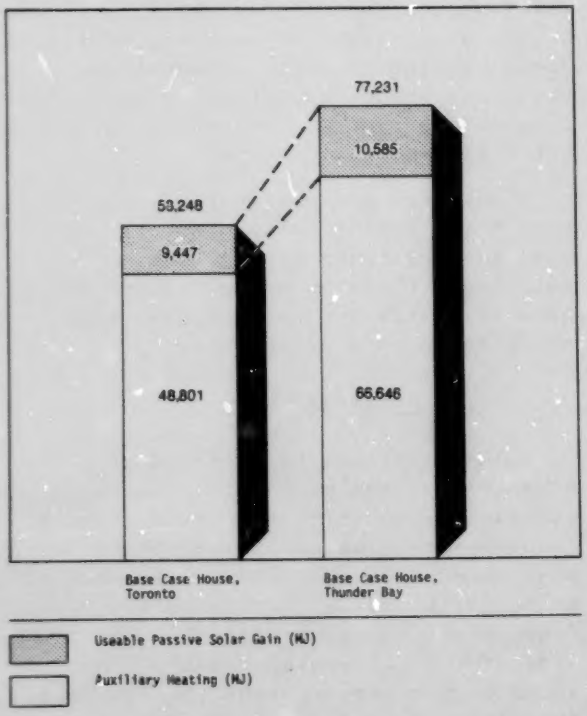
To assure maximum passive solar gain, the elevation with the greatest window area should face south (within a

TABLE 1.2

GEOGRAPHIC VARIATION

ITEM	BASE CASE: TORONTO	THUNDER BAY
Degree Days	4082	5746
Roof R Value	5.52 $m^2°C/W$	6.52 $m^2°C/W$
Wall R Value	3.14 $m^2°C/W$	3.64 $m^2°C/W$

Figure 1.5
Change in Auxiliary Heating and Passive Solar Contribution: Toronto vs Thunder Bay



range of 15-20° east or west of due south). Although the maximum solar gain results from facing due south, the optimum orientation is actually 5-10° east of due south. This orientation has proven to be optimum because it allows earlier warm-up of the house each day. The increase in solar energy during the late morning has a greater effect in assisting space heating because the house requires more heat in the morning to offset the cooler air temperatures from the previous night.

Ideally, planners, developers and builders should select lots which allow unobstructed south orientation of the elevation that will permit the largest window area. The trend to relatively narrow side yards to keep lot costs low usually results in little opportunity for unobstructed solar access to side elevations. This means that east-west streets are to be preferred for builders' houses designed to take most advantage from solar gain. The need to place the garage on the street side of the house suggests that houses on the south side of east-west streets provide the greatest opportunity for solar gain because the garages for those houses face north and therefore do not shade the heated envelope.

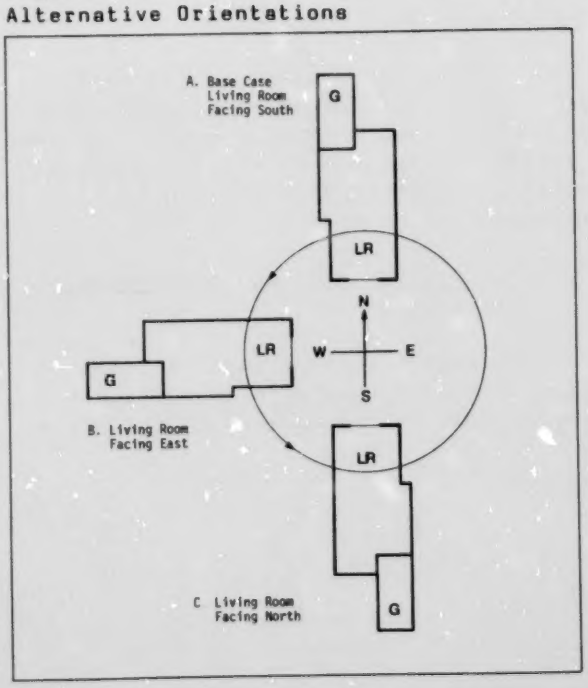
However, if the maximum window area on any elevation is less than 4-5% of the total floor area of the house (excluding basement), orientation is not highly significant in reducing auxiliary space heating energy. Orientation begins to become important as the window area on any one wall exceeds 5-6% of the total floor area.

Builders and designers should site each house on its lot so that if there are existing trees or adjacent buildings, these do not block the sun's rays from striking the building from mid-morning to mid-afternoon.

1.3.2 Example

To illustrate the effects of orientation, the base case house with its living room elevation facing south (equivalent to being placed on the south side of an east-west street) is rotated so that the living room faces east (equivalent to being placed on the east side of a north-south street). The house is rotated a second time so that the living room faces north (equivalent of being placed on the north side of an east-west street). See Figure 1.6. To

Figure 1.6
Alternative Orientations



further compare the effects of changing orientation, the same sets of orientations were computed for the Thunder Bay location. The orientations and window areas are listed in Table 1.3. The results are illustrated in Figures 1.7A and 1.7B. In all cases it is assumed that the narrow width of the side yards prevents solar gains on the side elevations.

These results indicate that changes in orientation provide a reduction in passive solar contribution and a corresponding increase in auxiliary space heating. The effect of the changes in orientation is proportionately greater in Thunder Bay due to the increase in available vertical surface solar gain from the south in that more northerly location.

However, because the glass area in the original south facing elevation is less than 5% of the total floor area, the reduction in solar gain is not significant. For a house with extensive glazing facing south and a highly insulated envelope there would be a significant drop in usable passive solar gains as the orientation varies away from south.

1.4 SOLAR GAIN THROUGH GLAZING

For conventional houses of the type built by merchant builders across Canada, windows provide the main method of collecting solar energy. Too much window area can lead to over-heating when the sun is shining and/or too much heat loss on cloudy days and at night due to the low R value of two or even three layers of glass. The discussion below assumes that south glazing has an unobstructed view of the south sky.

TABLE 1.3

CHANGES IN ORIENTATION OF MAIN GLAZING

WALL NO.	WINDOW AREA	LIVING ROOM FACING SOUTH	LIVING ROOM FACING EAST	LIVING ROOM FACING NORTH
1	5.52 m^2	South	East	North
2	1.48 m^2	West	South	East
3	2.02 m^2	North	West	South
4	5.25 m^2	East	North	West

Figure 1.7A
Effects of Change in Orientation - Toronto

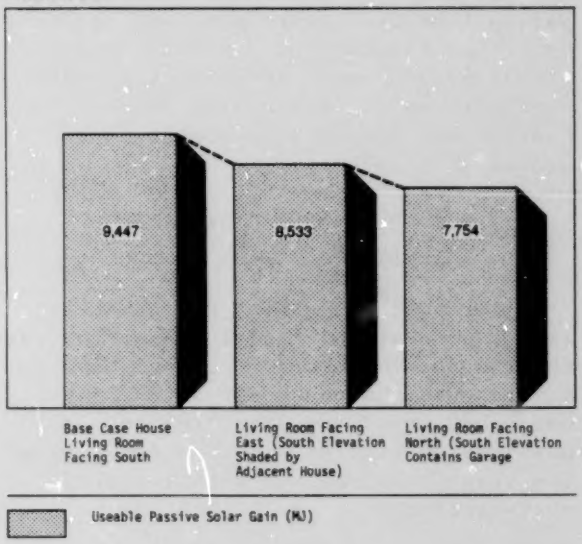
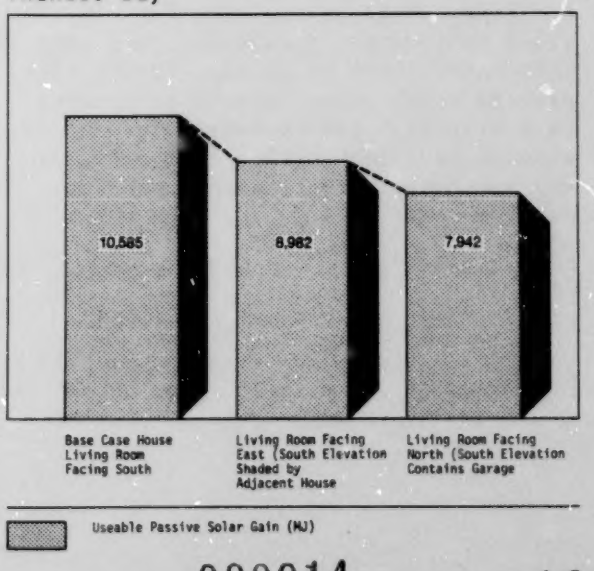

9,447
8,533
7,754
Base Case House Living Room Facing South
Living Room Facing East (South Elevation Shaded by Adjacent House)
Living Room Facing North (South Elevation Contains Garage
Useable Passive Solar Gain (MJ)

Figure 1.7B
Effects of Change in Orientation - Thunder Bay

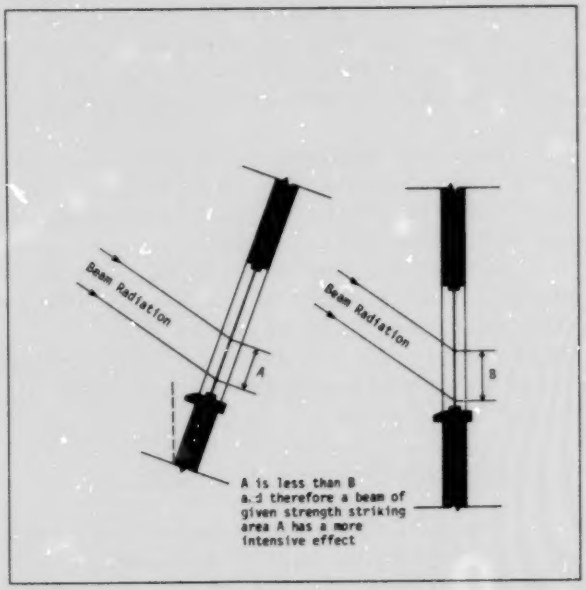

10,585
8,982
7,942
Base Case House Living Room Facing South
Living Room Facing East (South Elevation Shaded by Adjacent House
Living Room Facing North (South Elevation Contains Garage
Useable Passive Solar Gain (MJ)

1.4.1 Solar Energy Transmittance

Ideally windows should allow solar energy to pass through with minimum interference while at the same time provide high resistance to conductive heat flow. Ordinary window glass meets these requirements only partially. Solar energy transmittance can be increased through the use of low-iron glass, plastic film to replace the middle pane in a triple glazing system and use of anti-reflection films and finishes. For discussion of resistance to heat flow through windows, see Section 1.7, Low Energy Features.

Moderately inclined glass (20-30° from the vertical for Ontario locations) collects more winter solar energy than vertical glass because the rays are striking the glass at an angle closer to 90° producing more intensive radiation per unit area of glass and less reflection. See Figure 1.8. This advantage is offset by increased construction costs, difficulties in controlling water leakage and increased overheating problems in summer.

Figure 1.8
Moderately Inclined Glass Receives Beam Radiation More Intensively than Vertical Glass



1.4.2 Orienting Glass Area to the South

As indicated above, the greatest amount of available solar energy is from the south. Therefore, designers should ensure that the south elevation of the house has as much window area as possible consistent with the function of the rooms involved and with avoiding over-heating.

Windows usually have the lowest insulating characteristics (per m^2) of any other element in the building envelope. Therefore windows on elevations that do not face south (and therefore have little or no opportunity to provide solar gains) should be reduced to a minimum. Appropriate placement of windows is a low-cost/no-cost measure and is highly effective in enhancing passive solar gain.

However, increasing south glass beyond minimum requirements considered necessary for functional and marketing reasons, should be considered only if triple glazing or double glazing with night-time shutters is used (only windows with these features consistently provide a net energy gain in mid-Winter). Significant increases in south glazing may also require additional thermal mass to provide a means of storage for the added solar gain (see Section 1.6, Monthly Solar Gains Utilization Efficiency and Thermal Storage).

Triple glazing and/or increased thermal mass will add cost to the house. Therefore the benefits of increased usable solar gain must be compared to the added cost to be sure that these features are practical (see Section 1.9, Combining Features in an Optimum Manner).

1.4.3 Rules of Thumb for Alternative Amounts of Glazing

One of the key decisions to be made in the design of a passive solar house is to optimize the amount of glass area on the south elevation to avoid overheating. This overheating occurs when the temperature rises above the thermostat setting beyond an acceptable point. This rise in temperature due to solar gain is called the temperature swing (see Section 1.6.1).

Although the maximum allowable south glass area depends upon several variables, the following approximate rules hold for Ontario climatic conditions:

1. Assume the following:

   a) clear glass area is about 75% of the rough window opening (including the window frame and mullions);

   b) total room surface area is approximately four times the floor area.

2. Then, to limit south room temperature swing to 7 C degrees during sunny winter days:

   a) for light construction (standard wood frame and drywall) the gross window area for any south facing room should not exceed 12-15% of the floor area of that room;

   b) for partially heavy construction (i.e. 50% of walls, ceiling, floor area, use double layer drywall, brick or block feature walls, tile floor, concrete floor), the gross window area of each south facing room can be increased to 18-22% of the floor area of that room.

   c) if all of the enclosing surfaces of the room are of heavy construction, then the glass area can be increased to 36% of the floor area of that room.

In summary, the rule of thumb formula giving the glass area in south facing rooms as a percent of the floor area of such rooms is:

- $12\% \times 3/(3-2F)$

  Where F is the fraction of heavy construction for the enclosing surfaces of the room (the 12% figure could be increased to 15% in Ontario regions above 4,500 degree days C).

It is assumed that the floor, whether of wood or concrete, is carpeted. If no carpet is used, the effectiveness of the mass will be improved.

Another method of controlling temperature swing is to provide high wall returns to the central forced air distribution system. By running the furnace fan (or specially installed booster fans) continually, the warm southern portion of a house can be coupled to the cooler northern portions of the house to get better distribution of the solar heat gain. However, ducts and booster fans may result in additional costs that are not in proportion to the energy savings obtained. Heating contractors should confirm the cost effectiveness of such equipment using the temperature swing calculations provided in Part Three and size ducts and booster fans accordingly.

1.4.4 Example

To illustrate the effect of the amount of window area, Table 1.4 indicates the increase in south glazing from the base case. In addition, the south windows are triple glazed. All other energy features remain the same as for the base case house.

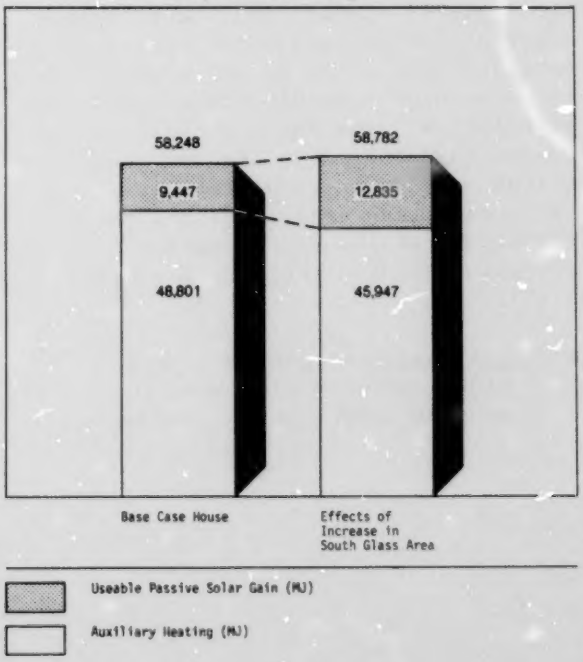
Figure 1.9 illustrates the increase in passive solar gain and the decrease in auxiliary space heating. Note that the net heat load has increased due to replacement of a portion of wall with glass (even with triple glazing, the windows have a lower R value than the walls). However, this increase is more than offset by increased solar gain, resulting in a lower auxiliary heating requirement.

TABLE 1.4

EFFECTS OF INCREASE IN SOUTH GLASS AREA, AND USE OF TRIPLE GLAZING

ITEM	BASE CASE:	INCREASE IN SOUTH GLAZING
South Window Area	5.52 m^2	9.88 m^2
Layers of Glazing	Double	Triple

Figure 1.9
Effects of Increase in South Glass Area and Use of Triple Glazing



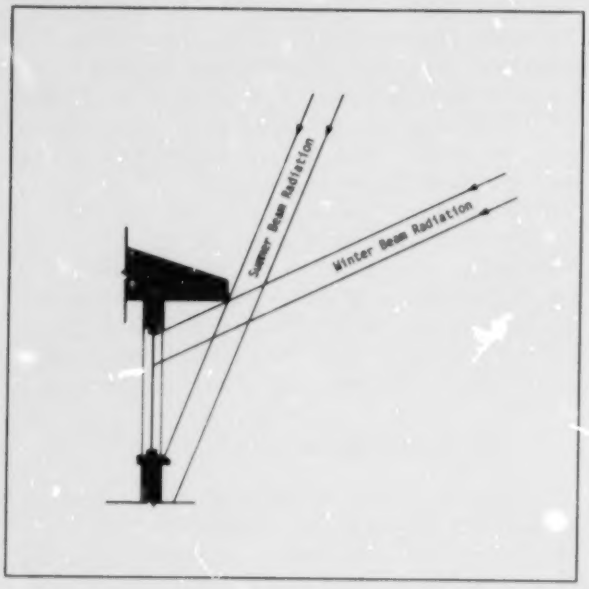
1.5 SHADING EFFECTS

Shading is caused by landscape and/or man-made objects on and/or off the building site. It reduces the available solar energy by preventing the sun's rays from striking the building envelope.

1.5.1 Significance of Shading

In summer, shading may be necessary to reduce unwanted heat gain (See Figure 1.10). Properly designed shading devices can block solar penetration through windows in summer (and reduce the need for mechanical cooling) while permitting the lower angled winter sun's rays to enter. The extent of shading varies by month due to the change in the angle of the sun's rays. The relatively low angle of the sun in mid-winter creates the longest shadow length at a time when passive solar gain is most important. Walls or coniferous trees should be located to avoid screening the winter sun. However, early morning and late afternoon shade is not as significant as blocking of the sun's rays in the middle of the day, because beam radiation from early and late sun is less intensive.

Figure 1.10
Overhang Designed to Maximize Winter Solar Gain, and Minimize Summer Solar Gain

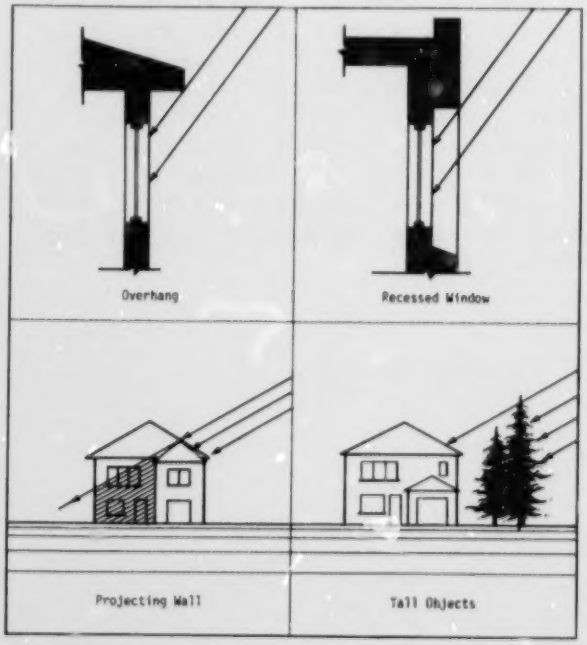


1.5.2 Types of Shading

There are several types of shading. These are worth recognizing by the designer and builder, because some types should be considered during the detailed design stage, where others must be treated by careful site planning and orientation. The shading elements that cannot be modified by the designer or builder should be recognized as such so as to more accurately estimate their effects on the house. Elements producing shading include (See Figure 1.11):

- Overhangs; projected floors; cantilevered sun screens (to provide summer shade) and eaves.

Figure 1.11
Alternative Means of Shading



- Recessed Windows; windows set into walls whose thickness is increased to provide added insulation.

- Projecting Walls; the plan outline of the house itself may put one or more portions of the south elevation in shadow for part of the day.

- Tall Objects; parts of nearby buildings or structures and trees.

The manual considers shading calculations to be a refinement of the calculation procedure. Therefore, detailed calculations for shading effects are found in Part Three.

1.5.3 Example

To illustrate shading effects, Table 1.5 shows the new shading factors as a result of a sun-screen on the base case house on the ground floor and second floor south windows. The sun-screen has been designed to reduce unwanted summer gains, while keeping winter gains as high as possible. Figure 1.12 shows the comparative change in passive solar gains and in auxiliary space heating. The relatively small increase in auxiliary heating has been offset by the increased comfort in summer.

1.6 MONTHLY SOLAR GAINS UTILIZATION EFFICIENCY AND THERMAL STORAGE

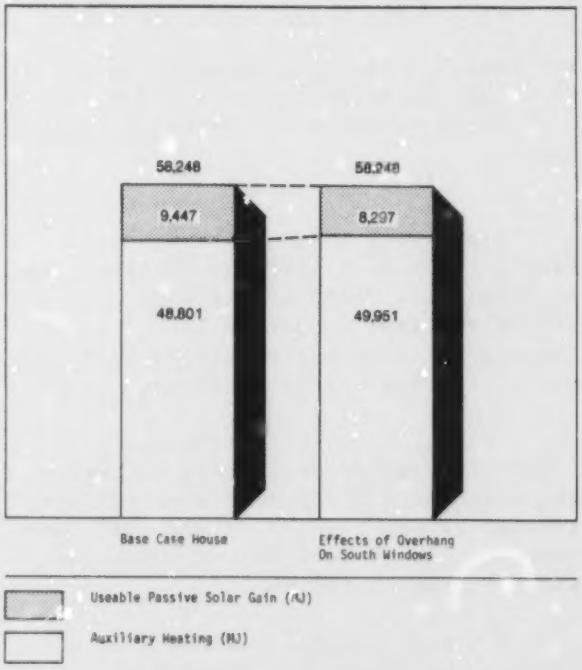
At any point in time during a sunny winter day, some of the available passive solar gains may be surplus to the heating needs of the house. If a house has a means of storing these gains for use later when auxiliary space heating is needed, then greater utilization can be made of solar energy. If this energy cannot be used and cannot be stored at the time it is available, overheating will result. This in turn would result in increased heat losses and therefore lower utilization of solar gains. More of the solar gains will be used to offset such increased losses.

TABLE 1.5

EFFECT OF SHADING DUE TO OVERHANG ON SOUTH WINDOWS

BASE CASE	OVERHANG VARIATION
Shading only on kitchen window by virtue of projecting wall	In addition, shading on living room and bedroom windows provided by 3' overhang placed 1' above top of window

Figure 1.12
Effects of Shading Caused by Overhang on South Windows



1.6.1 Definition and Significance of Monthly Solar Gains Utilization Efficiency

Not all of the solar gains can be used to reduce auxiliary heating energy requirements. The monthly solar gains utilization efficiency is the proportion of monthly solar gains (average hourly solar gains summed for all days in the month) that can be used to reduce the net heating requirement. Even if the monthly solar gains happen to be exactly equal to the net monthly heat loss, there would still be a considerable mismatch between supply and demand. This is because heating is required not only during sunny days but also during cloudy days and at night. The monthly solar gains utilization efficiency is dependent upon two factors:

- the ratio of monthly solar gains to the monthly heat load (monthly heat loss less monthly internal gains) called the solar load ratio, and
- the availability of dense surface materials in primarily south facing rooms to serve as thermal storage.

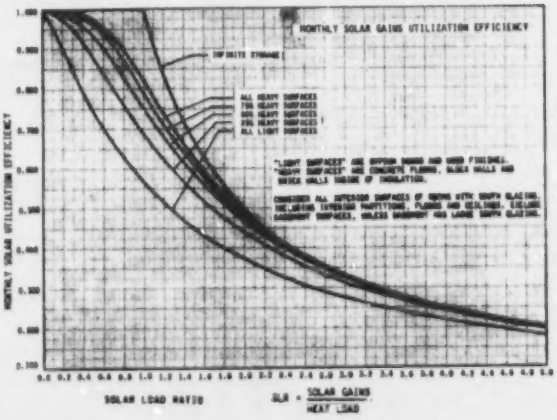
Thermal Storage

Increasing thermal storage in south facing rooms will serve to increase the monthly solar gains utilization efficiency (see Figure 1.13). Therefore, designers should be aware of how to improve thermal storage.

As indicated in Section 1.4, lightweight surfaces consist of gypsum board and wood finishes; heavy surfaces consist of brick walls, block walls and concrete floors that are on the indoor side of the insulation.

The most important surface in a room is the floor because most of the time the suns rays reach the floor first, and then are reflected onto the remaining surfaces. Therefore, although a room has in fact only six surfaces (floor, ceiling and four walls), for purposes of calculations, the floor counts for three surfaces for

Figure 1.13
Monthly Solar Gains Utilization Efficiency



For large values of SLR (beyond the range of the Graph): Monthly Solar Gain Efficiency = $\frac{1}{SLR}$

a total of eight surfaces in the room. The fraction of heavy surfaces in a room is estimated by counting the number of heavy surfaces and dividing that number by eight. For example, a room with a concrete floor will have about 40% heavy surfaces. If the southern portion of the house has two rooms with a significant amount of south glass, then there are two times eight equals 16 surfaces to consider. A feature brick wall between the two rooms would count as two heavy surfaces. A concrete floor in one of the rooms would add another three surfaces for a total of five heavy surfaces in 16, or about 30% heavy surfaces.

Temperature Swing

As indicated above, temperature swing is the extent to which solar gains cause the temperature in south facing rooms to rise above the thermostat setting. If the temperature swing is too high, the room may become uncomfortable. Means of reducing the temperature swing include:

- reducing the area of south glazing;
- increasing the construction mass to provide greater thermal storage;
- providing fans to move air from rooms with south glazing to other parts of the house.
- temporarily blocking the entry of the sun's rays;
- venting of excess heat to outdoors;

The last two methods should not be considered during the winter months because they eliminate the beneficial solar gains of larger south glass areas, while retaining the detrimental increased heat losses of such larger glass areas. Furthermore it would not be practical or reasonable to require the occupants to vent their houses in cold weather. Shading and venting in milder weather is more acceptable.

The relationship between monthly solar gains utilization efficiency, thermal mass and temperature swing is discussed below.

Figure 1.13 indicates the monthly solar gains utilization efficiency for a 5 C degree temperature swing. This means that given a monthly solar load ratio and a percent of heavy surfaces, the resulting solar utilization efficiency would correspond to having a maximum increase of 5 C degrees above the thermostat setting during sunny winter days (i.e. a maximum temperature swing of 5 C degrees).

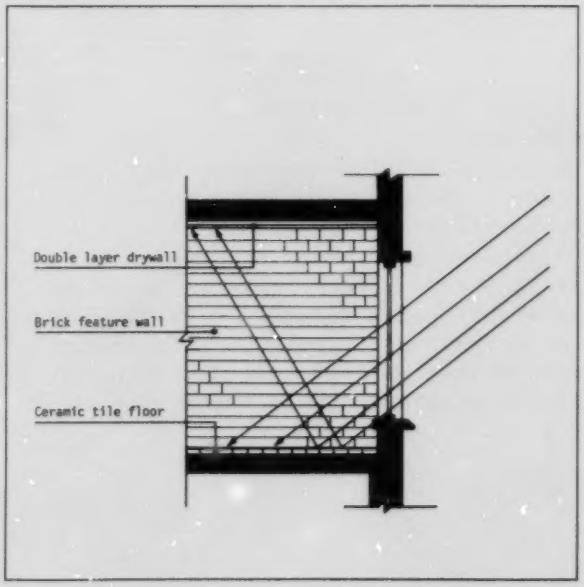
As a general rule, the designer should limit the temperature swing to between 3 and 7 C degrees, appreciating that this increase above the thermostat setting will happen only for a few hours at mid-day during completely clear winter days. Increasing the mass beyond this point can increase the monthly solar gains utilization efficiency. Such additional mass would have to be justified economically by savings in space heating costs. The efficiency graph lines in Figure 1.13 also show why it makes sense to provide a small amount of additional thermal storage mass, and why adding larger amounts of mass will provide a reduced benefit.

Some Ways of Providing Thermal Mass

As indicated above, thermal mass increases the efficiency of the collection of solar energy and can help reduce temperature peaks during sunny days. Cost-effective ways of providing thermal mass include the use of extra thick or double layer drywall and use of interior masonry partitions of brick or concrete block (See Figure 1.14). Masonry exterior walls with the insulation placed on the outside can also be considered. Massive floors should preferably not be covered with carpets.

The mass of the basement may be used if special air circulation fans and

Figure 1.14
Types of Thermal Storage Material



ductwork are installed for this purpose. The basement walls and floor must be well insulated on their outer surfaces in this case. However tests have indicated that this form of thermal storage is not highly effective because solar radiation does not strike the mass directly.

The thickness of massive elements is not effective beyond 30 to 50 mm. Painting of the massive components in darker colours has little effect. This is due to the fact that solar radiation is trapped inside the room and very little of it can escape even with light coloured finishes. This can be seen by looking at a window from the outside on a sunny day and noting the almost black appearance of a window without curtains, regardless of the colour of the interior finishes. Anything that makes the window appear lighter (eg. curtains, objects on the inside near the windows) will correspondingly reduce the collection of solar energy.

A rock-filled bin with ducts and a special fan can be used as additional mass. Effective use of storage in such a bin is directly proportional to the temperature swing, and therefore generally involves the creation of hot pockets with temperatures higher than those acceptable in the living space. It should be noted in this regard that thermal mass located directly in the space receiving the solar radiation works more efficiently as it can store substantial quantities of heat without any temperature swing.

1.6.2 Example

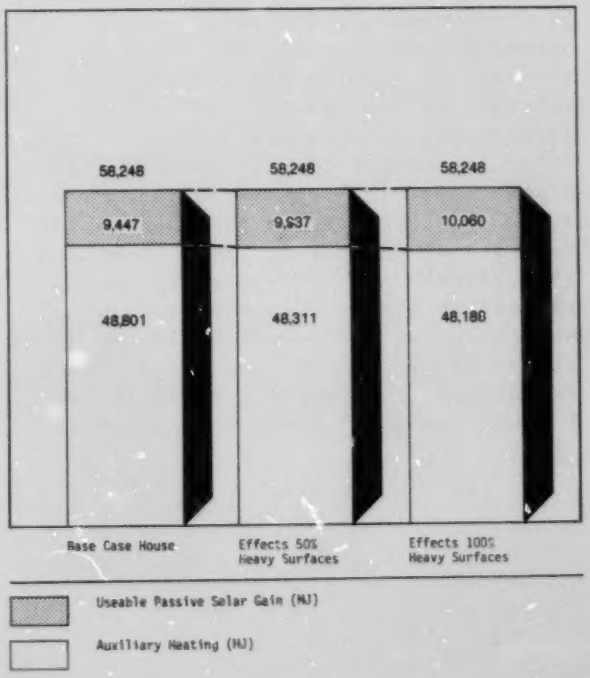
Table 1.6 indicates the change in percent of heavy surfaces from the base case house, using 50% and 100% heavy surfaces. Figure 1.15 shows the corresponding increase in the monthly solar gains utilization efficiency and the reduction in auxiliary space heating. Effects of added thermal mass become significant only with designs using large south glass areas (producing a high solar load ratio).

TABLE 1.6

INCREASE IN % OF HEAVY SURFACES

BASE CASE	ALTERNATIVE A	ALTERNATIVE B
All light surfaces	50% heavy construction	100% heavy construction

Figure 1.15
Effects of Increase in Heavy Surfaces on Monthly Solar Gain Utilization Efficiency and in Auxiliary Space Heating



1.7 Low Energy Features

Low energy features generally consist of measures to reduce heat loss through the building envelope and the use of more efficient heating equipment and appliances. These are not directly related to passive solar features; but they are included in this manual because they form part of the range of considerations for designers and builders in producing energy efficient new housing.
This section deals with these features in summary form. More detailed information is found in publications listed in Appendix F, Further Reading.

These low energy features are briefly reviewed under the following headings:

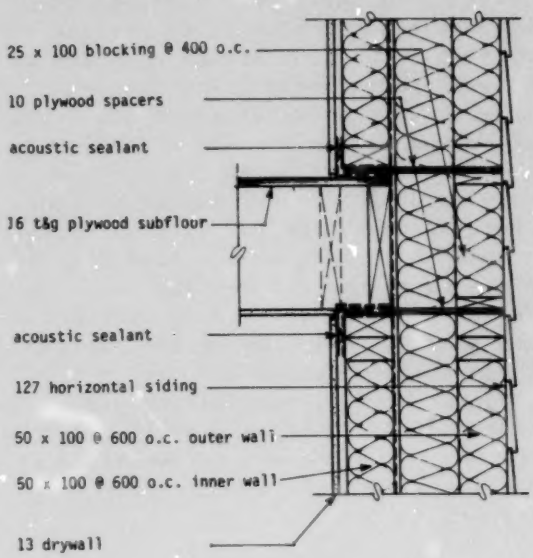
- wall insulation;
- ceiling insulation;
- airtightness;
- windows;
- basement insulation;
- heating equipment;
- appliances.

1.7.1 Wall Insulation

The wood frame stud wall is the most prevalent and economical construction in Ontario. The stud space is normally filled with glass fibre batt insulation. Improvements can be achieved by the use of higher grade insulation, such as higher density glass fibre. Deeper studs can be used with proportionately more insulation. Insulating sheathing can be attached to the exterior of the studs. Such sheathing is available with very high thermal resistance levels. This exterior sheathing must be carefully installed as it can transform the stud space into a "stack" and induce air circulation up through the glass fibre insulation if

even small cracks near the bottom and near the top of the stud space exist. Another approach that also helps with the installation of the vapour barrier, is interior horizontal strapping with additional insulation in the space provided by such strapping. Very large amounts of insulation can be installed with special wall constructions, such as double frame walls (See Figure 1.16) and walls with stand-offs for the creation of a deep insulation space.

Figure 1.16
Double Stud Construction


25 x 100 blocking @ 400 o.c.
10 plywood spacers
acoustic sealant
16 t&g plywood subfloor
acoustic sealant
127 horizontal siding
50 x 100 @ 600 o.c. outer wall
50 x 100 @ 600 o.c. inner wall
13 drywall

Particular care must be taken with the detailing of the wall at corners, floor header areas, window openings and similar locations where traditional methods cause thermal bridges because of the amount of wood used and cracks that allow infiltration of outside air.

Note that additional building envelope insulation will result in reducing useful solar gain for two reasons:

1. the insulation prevents the transmission of solar energy from the outside to the inside;

2. the reduced rate of heat loss from inside the dwelling means that less of the passive solar gain is usable for a given window size and weight of construction (however this is usually offset by the greater reduction in auxiliary heating).

1.7.2 Ceiling Insulation

Generally there are few impediments to the upgrading of ceiling insulation, particularly with attic type roofs. Ensure adequate compaction of loose insulation and avoid obstructing the necessary attic ventilation at the eaves.

1.7.3 Airtightness

In addition to preventing condensation problems in the insulation layer, the polyethylene air/vapour barrier prevents air flow in both directions through the building envelope. The infiltration of outdoor air often represents 1/3 or more of the

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heating load. Therefore careful installation of the air/vapour barrier, as well as sealing of cracks at doors and windows, are the most cost-effective energy conservation measures. Electrical wiring and outlet boxes often pierce the plastic barrier and are difficult to seal. One approach to overcome this problem is to provide an additional interior strapping space as discussed previously. The vapour barrier is then installed on the studs behind such strapping while the wiring is run in the strapping space, thus avoiding damage to the vapour barrier. A rule of thumb for the Ontario climate is that if as long as not more than 1/3 of the total thermal resistance is on the warm side of the vapour barrier, then it is likely that no insulation condensation problems will be encountered, i.e. the temperature at the room side of the vapour barrier will be high enough to prevent condensation of interior air touching the vapour barrier.

An added method for sealing of the house against infiltration is to use a special film at the exterior of the wall. The film allows vapour to pass through but at the same time stops the airflow. The advantage of this method is that the integrity of such an air stopping envelope is easily maintained when it is installed on the outside of the house just before the application of the exterior siding or brick veneer.

Internally generated odours and contaminants require certain minimum ventilation rates. When using tight construction techniques designers and builders should be careful to ensure adequate combustion air for the furnace and the fireplace. Additional mechanical ventilation over and above the combustion equipment air requirements may be needed for the comfort and health of the occupants. One option for improving energy efficiency of this necessary ventilation is the use of an air-to-air heat exchanger.

1.7.4 Windows

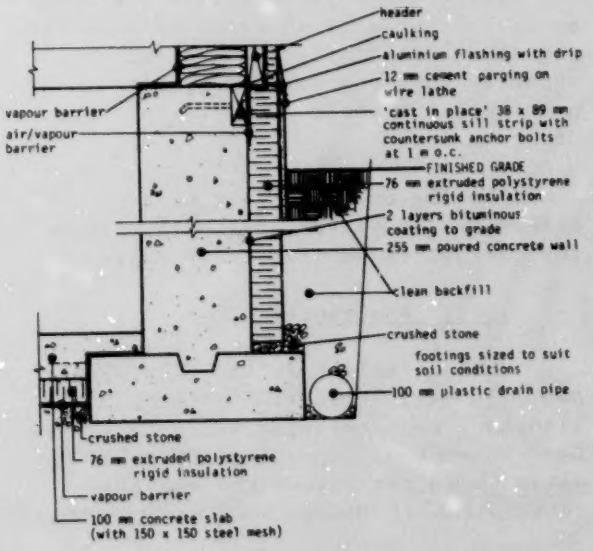
The ideal window should have high resistance to heat flow and at the same time allow the solar energy to pass through with minimal interference. Ordinary glass meets such requirements only partially. Windows with improved performance are being developed. Higher resistance to heat flow can be achieved from multiple glazings, infrared suppressing films, convection suppressing devices, use of low conductance gases or a vacuum between glazings and use of insulating shutters or blinds at night.

Double glazing should have about 16 mm between layers for optimum thermal resistance. With ordinary glass in the Ontario climate only triple glazing in the south exposure (or double glazing with night shutters) provides a definite net contribution to the heating of a house. If the south glazing area is increased from standard designs, then it should be triple glazed to save energy as well as increase solar gain. Increasing the area of south windows with double glazing will likely result in higher heating energy consumption. Glass in the north, west and east exposures (as well as horizontal skylight glass) is a net loser of energy. Replacement of a given area of double glazing with triple glazing will save more energy in the north, east and west exposures than in the south exposure. This is because triple glazing reduces heat losses by the same amount for all exposures, but cuts out more of the solar energy for the south exposure than for the exposures that have lower solar gains. This consideration applies only to the situation where the amount of glazing is fixed in each exposure.

1.7.5 Basement Insulation

In a well constructed house, basement losses can represent a major component of the total heating requirement. Basement walls should be insulated over the full height (See Figure 1.17). The effectiveness of basement floor insulation is affected by the depth of the water table and the conductivity of the soil, both of which

Figure 1.17
Exterior Applied Basement Insulation


header
caulking
aluminium flashing with drip
12 mm cement parging on wire lathe
vapour barrier
air/vapour barrier
'cast in place' 38 x 89 mm continuous sill strip with countersunk anchor bolts at 1 m o.c.
FINISHED GRADE
76 mm extruded polystyrene rigid insulation
2 layers bituminous coating to grade
255 mm poured concrete wall
clean backfill
crushed stone
footings sized to suit soil conditions
100 mm plastic drain pipe
crushed stone
76 mm extruded polystyrene rigid insulation
vapour barrier
100 mm concrete slab (with 150 x 150 steel mesh)

are difficult to determine with reasonable accuracy at a given location.The calculation forms assume dry clay and a water table several meters below the basement floor. The value of basement insulation is greater in wet ground which has higher heat conductivity than dry soils.

1.7.6 Heating Equipment

High efficiency furnaces have become available recently. Flame retention burners and automatic stack dampers are available for oil furnaces. Gas furnaces with intermittent pilot light and pulse, and condensing-type combustion produce more usable heat from the same amount of fuel. Infiltration can be reduced by the elimination of the chimney and the use of a combustion air duct direct from the outdoors to the burner. Night and mid-day temperature setback with the help of automatic thermostats can save substantial amounts of heating energy in homes with relatively low levels of insulation and airtightness; these devices are less effective in low energy houses.

It is important to ensure that the furnace is correctly sized for the house. In forced air systems, it is equally important that the air volume flow rate is sufficient to overcome all duct resistance to enable heat to reach all parts of the house. Even more important is the matching of the air volume flow rate to desired temperature pick-up across heating coil or heat exchanger. This is to ensure that the supply air at a given velocity does not create a "draft effect". Normal capacity furnaces do not present problems, but small capacity furnaces do.

The use of air-to-air heat exchangers in tight houses will reduce the energy needed from the furnace.

1.7.7 Appliances

More efficient refrigerators, air conditioners, TV sets, fluorescent lighting, recirculation of clothes dryer heat in winter, extra insulation on hot water tanks can reduce the overall consumption of energy and keep the house

cooler in the summer. They do not save energy during the heating months however, except for the recirculation of dryer heat. For very tightly built houses, recirculation of dryer exhaust air could aggravate the humidity problem.

1.7.8 Example

To illustrate some of these low energy features, the following example draws on insulation and airtightness features from a house design selected for the Ontario Ministry of Energy Low Energy Passive Solar Sub-Division Program. Table 1.7 indicates these low energy features and compares them with the corresponding features of the base case house. Figure 1.18 shows the effects of these upgraded features on passive solar gain and purchased space heating. Note that the useful passive solar gains are less than those of the base case. This occurs for two reasons:

- gains through opaque surfaces are reduced because of the heavier insulation levels
- less passive solar energy is needed because the rate of heat loss is lower, again due to heavier insulation levels, and also to improved airtightness.

Despite lower solar gains, the auxiliary space heating has also decreased because of the higher insulation levels. The contribution of passive solar gains as a percent of the net heat requirement (represented by the bar height in Figure 1.18) increases from 16% in the base case to 21% in the upgraded house.

Designers should check the temperature swings especially if existing house designs are being upgraded in terms of insulation and airtightness.

1.8 COMBINING THE FEATURES IN AN OPTIMUM MANNER

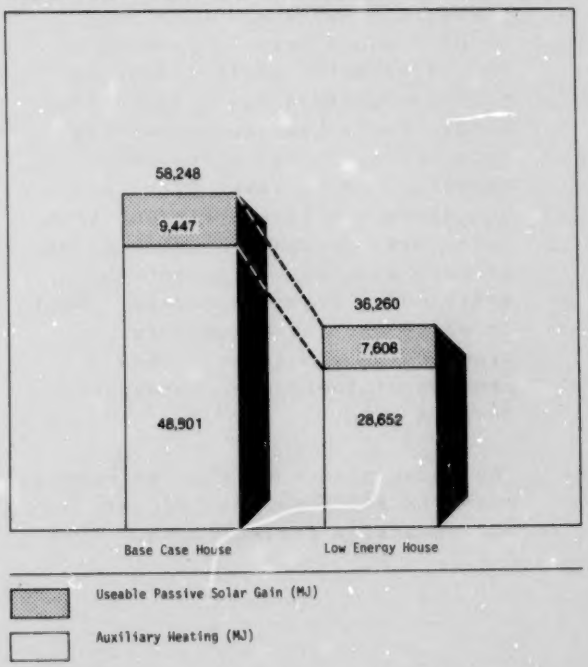
The wide range of features for increasing passive solar gain and for reducing heat loss can be combined in a variety of ways. It is important for the designer and builder to select the optimum combination so that the home owner has the greatest benefit for the

TABLE 1.7

INCREASED LEVELS OF INSULATION AND AIR TIGHTNESS

ITEM			BASE CASE	LOW ENERGY
Infiltration Rate			.3 air change/hr	.1 air change/hr
Forced Ventilation (with heat recovery)			0.0 m^3/hr	180.0 m^3/hr
Roof R value			5.52 $m^2°C/W$	7.20 $m^2°C/W$
Wall R value			3.14 $m^2°C/W$	5.30 $m^2°C/W$
Basement R values				
Above grade			1.90 $m^2°C/W$	3.80 $m^2°C/W$
Below grade			1.60 $m^2°C/W$	3.48 $m^2°C/W$
Floor			0.00 $m^2°C/W$	1.80 $m^2°C/W$
WALL NO	WINDOW AREA	ORIEN-TATION	LAYERS OF GLAZING	LAYERS OF GLAZING
1	5.52m^2	S	Double	Double
2	1.48m^2	W	Double	Triple
3	2.02m^2	N	Double	Triple
4	5.25m^2	E	Double	Triple

Figure 1.18
Effects of Increased Levels of Air Tightness and Insulation on Passive Solar Gain and Purchased Space Heating



lowest cost. This section reviews what measures should be selected as a matter of priority and how to measure the effectiveness of adding additional features.

Generally only the low cost/no cost passive solar features should be selected prior to using improved insulation, airtightness and furnace measures.

1.8.1 Selecting the Features

The following steps are meant to serve as a guide in selecting passive solar/low energy features. In general, no cost or low cost measures should be selected first, followed by the more costly measures for which pay back can be calculated:

1. As a preference, select lots that are on east-west streets. Lots on the south side of east-west streets offer the greatest design flexibility. Wide lots on the north side of east-west streets permit the opportunity to place the garage so that it blocks the least amount of the south elevation.

2. Site the house to avoid winter shading from adjacent buildings and evergreen trees.

3. Choose a house shape that is compact and simple in form to reduce exterior surface area as much as possible for a given floor area. Avoid garages projecting into the dwelling volume, and dormers. For a given floor area, bungalows are less efficient than two storey detached houses, which in turn are less efficient than split entry detached houses. Semi detached and townhouses are progressively more efficient because of their reduced exposed surface area.

4. The house plan should be as open as possible and have the largest living spaces facing south. This

helps reduce temperature swing by increasing the volume affected by solar gains.

5. Select house plans and elevation designs that permit large windows to face south. This means that for the house on the north side of an east-west street, garages should be placed leaving as much as possible of the south elevation exposed.

6. Place as much of the window area as possible on the south and reduce the window areas on the other elevations.

7. Use construction details that minimize air leakage and carefully seal joints during construction.

8. For forced air heating systems, use duct openings that will assist in coupling the northern portion of the house to the southern portion to assist in solar gains distribution and storage.

9. Consider the use of the high efficiency furnaces for space heating. Check if the energy savings in relation to the furnace price premium are acceptable (i.e. payback, see below).

10. Place as much insulation as possible in the walls as a priority. Ceiling insulation is also important, but this can usually be added later as a retrofit item.

11. If the area of south glazing is to be significantly increased from that of standard designs, use triple glazing for the south windows.

12. For electric baseboard, radiant and hydronic heating systems, consider adding ducts and a fan to assist in solar gain distribution and storage.

13. Add heavy construction to south-facing rooms to increase the thermal storage effect.

14. Add an attached unheated sun space such as a covered glazed porch on the south which could serve as an extension of the indoor area on sunny winter days.

1.8.2 Estimating Payback

The energy conservation features included in the first eight of the above steps usually involve little or no additional cost to the price of the house. The remainder will have varying costs and benefits. These can be measured in terms of payback, which is the length of time in years required for the additional purchase price to be offset by energy savings. Simple payback for a given energy conservation feature is calculated by dividing the construction cost premium for that feature by the annual energy cost savings provided by the feature (this assumes that interest rates will equal energy cost inflation rates). Generally, additional energy-saving features should be added in the order of fastest payback, considering energy consumption of that particular feature together with the reduced energy consumption of features already selected.

For example, having decided to implement the features in the first seven steps for a selected house design, and wishing further reductions in space heating requirements, the builder may want to compare the benefits and costs of adding a condensing gas furnace to those of adding a ceramic tile floor in south-facing rooms and a masonry feature wall between these rooms. To select the preferred feature(s), determine the purchase price <u>premium</u> for each of them in comparison to the standard furnace and standard floor and wall construction. Then use the forms in Part 2 or Part 3 to calculate the different energy requirements for each of the two features as compared to the base case, assuming the other features selected in Steps 1 through 8 are in place. Determine the payback periods for the condensing gas furnace option

and for the heavy construction option. The feature with the shortest payback should be preferred. However if the paybacks are both under 4-5 years, then the feature with the largest annual dollar savings may be preferable. If the payback period for both of the options exceeds 8 to 10 years, then it is likely that neither should be selected, because it is considered that a payback beyond this range has little appeal to the average home buyer.

These paybacks could be compared with those of adding more insulation to walls and ceilings. It could be that this last option should be preferred because it could have the shortest payback.

An alternative measure of cost-effectiveness of energy-conserving features is the extent to which annual energy cost savings offset the increase in annual principal and interest payments which result from installing the features that produce those savings.

Using simple payback or principal and interest offset, designers and builders can clearly evaluate what features to select. Parts Two and Three indicate how to determine thermal effects of the above features.

PART TWO: SHORT FORM CALCULATIONS

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2.3 How the Calculation Forms are Organized.....2-3

Short Form Calculation Forms

PART TWO: SHORT FORM CALCULATIONS

Part Two provides a quick method of estimating heating loss and energy requirements, taking into account the basic contribution of passive solar gains.

2.1 INTRODUCTION

The short form calculations enable designers and builders to quickly evaluate the main factors of low energy/ passive solar design in new and existing housing. These calculations enable rapid comparison of alternative house designs and comparison of alternative energy conserving and passive solar features for a given basic dwelling design. Designers and builders can quickly determine the extent of energy savings provided by various building components. By combining this knowledge with the related construction costs, they can estimate payback lengths to select the optimum group of energy conserving features.

2.2 HIGHLIGHTS OF SHORT FORM PROCEDURE

The short form procedure accounts for all the main energy use factors, with some modifications to simplify the calculations and to account for alternative window treatment. Calculations for walls, ceilings, and above grade basement walls are performed using the R value of the insulation only. The additional insulation value of sheathing and air films is partly offset by framing losses and is small in comparison to the insulation R value.

Builders have a choice in the calculations of window R value depending upon the number of layers of glass. This enables testing of the effectiveness of triple glazing as compared to double glazing for increased window areas on the south elevation.

As a simplification, only solar gains on unobstructed, unshaded south windows are considered, because the

primary contribution of solar gain is on the south elevation. The presence of shading features can be determined in advance and these are often independent of the house design.

Soil conditions are assumed to be dry clay with the water table several meters below the basement floor.

Users of the forms can estimate the air change rate depending on the age of the house, the nature of its construction and its heating system. Air change can account for a significant portion of the total heat loss.

Allowance is also made for the effects of mechanical ventilation and the use of air-to-air heat exchangers. It is generally recommended that if the air leakage rate is less than 0.5 air changes per hour, a mechanical controlled ventilation system should be installed.

The procedure does not consider heat loss through special wall or ceiling construction. Projected floors and attached unheated sun spaces are also not included in the procedure.

All units including those for R values are metric.

Results from the above procedure can provide a reliable selection of house designs and individual energy conserving features. The purchased space heating requirement is within 10-15% of the results produced by the fully detailed procedure in Part Three, and is accurate enough to serve most purposes. The relative speed of obtaining results will make the short form calculations most useful for builders.

2.3 HOW THE CALCULATION FORMS ARE ORGANIZED

The short form procedure is organized on four forms. The fourth form is actually the monthly solar gains

utilization efficiency chart. One complete blank set for purposes of photocopying is included following these notes.

Additional information for climatic and R value information is provided in Appendices A and B.

Form S-1 deals with:

A window losses;

B ceiling losses;

C door losses;

D wall losses;

E basement wall above grade losses;

F infiltration losses;

G total above grade heat loss co-efficient.

Form S-2 covers:

H basement wall below grade losses;

I basement floor losses.

Form S-3 provides:

J gross monthly heat loss calculations;

K heating energy requirement calculations.

Form S-4 consists of:

L monthly solar gains utilization efficiency graph and explanatory notes.

Appendix C provides a set of short form calculation forms which have been completed for the analysis of a typical merchant builder house in Mississauga. This house has been selected to illustrate the various aspects of the calculation forms. It can be used for reference for working through the short form calculations.

PROJECT NAME _____

LOCATION _____

HEAT LOSS CALCULATIONS - SHORT FORM

For Wall, Ceiling and Basement Wall Above Grade R-values it is satisfactory to use the R-value of the INSULATION ONLY, since the additional resistance of air films and finishing materials is offset by adjustments for wood studs.

Use the more detailed calculation forms where shading effects, solar gains through other than south glazing, or special wall or ceiling construction have to be considered.

All units are metric, including insulation R values

A WINDOW LOSSES

WINDOW AREA (m2) Window dimensions to include frames, ie. use gross wall opening dimensions. Include sliding glass patio doors and basement windows. [1]

WINDOW R-VALUE (Cm2/W)
.22 for single glazing
.61 for double glazing
.61 for triple glazing [2]

WINDOW LOSS (W/C)
Divide Line 1 by Line 2 [3]

B CEILING LOSSES

CEILING AREA (m2) [7]

CEILING R-VALUE (Cm2/W) [8]

CEILING LOSS (W/C) [9]
Divide Line 7 by Line 8

C DOOR LOSSES

DOOR AREA (m2) [10]

DOOR R-VALUE (Cm2/W) [11]
35mm wood with metal storm .63
45mm Steel with urethane core .68

DOOR LOSS (W/C) [12]
Divide Line 10 by Line 11

D WALL LOSSES

WALL TYPE	A	B
Description		
WALL AREA (m2) Gross wall area minus window area and minus door area. Use inside house dimensions.	[4A]	[4B]
WALL R-VALUES (Cm2/W) (Multiply Imperial R values by .1761 to convert them to metric.)	[5A]	[5B]
WALL LOSS W/C	[6A]	[6B]

Divide Line 4 by Line 5
E.g. 6A / 5A = 6A

E BASEMENT WALL ABOVE GRADE LOSSES

AREA (m2) [13]
Wall area minus glass in basement wall above grade.

R-VALUE (Cm2/W) [14]

LOSS (W/C) [15]
Divide Line 13 by Line 14

F INFILTRATION LOSSES

AIR CHANGE RATE Use measured infiltration AIR CHANGES/HR or the following estimated values:

-Older house (pre 1976)	1.0+ AC/hr
-Conventional construction (fossil fuel)	0.5 AC/hr
-Carefully constructed fossil fuel or average electrically heated house	0.3 AC/hr
-Super energy efficient air tight construction	0.05 - 0.1 AC/hr

Use .3 for the last case if there is no forced ventilation with heat exchanger. [ ] AC/hr (16)

HEATED VOLUME Include semi-basement rooms that have walk out doors or large windows. Include 1/2 volume for normal basement spaces.
[ ] m3 (17)

FORCED CONTINUOUS VENTILATION
[ ] m3/h (18)

FORCED VENTILATION HEAT EXCHANGER EFFICIENCY
[ ] % (19)
Assume 70% if actual efficiency not available.

INFILTRATION LOSS

[16] x [17] x [18] x (100 - [19]) / 100 x 0.3345 = [20] W/C

G TOTAL ABOVE GRADE LOSS COEFFICIENT

Sum all the previously calculated losses.

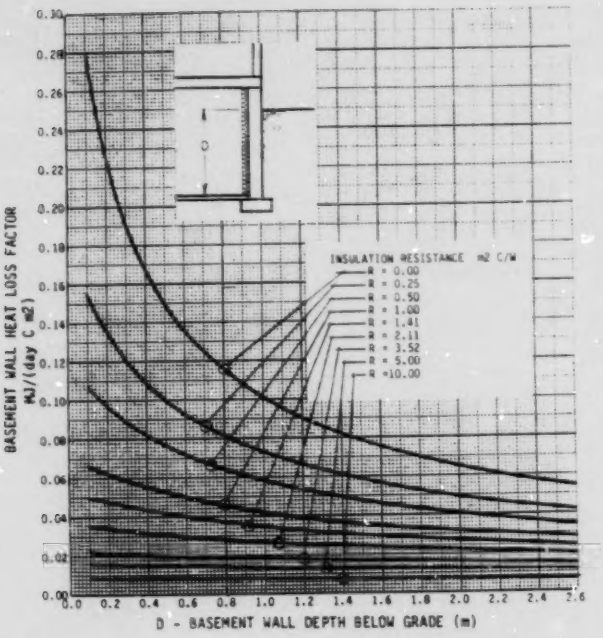
The total above grade loss coefficient excludes below grade basement losses and must not be used to size equipment.

Window Loss	[3]
Wall Loss (type A)	[6A]
Wall Loss (type B)	[6B]
Ceiling Loss	[9]
Door Loss	[12]
Basement Wall Above Grade Loss	[15]
Infiltration Loss	[20]

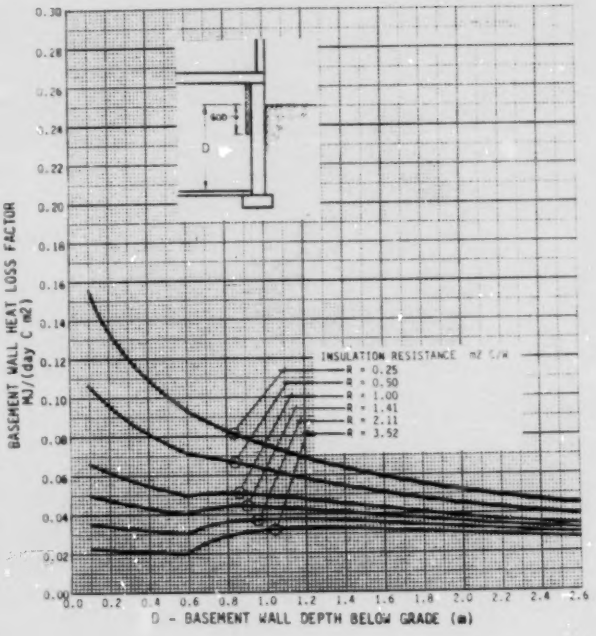
TOTAL Above Grade Loss Coefficient = [42] W/C

H BASEMENT WALLS BELOW GRADE

Full height basement wall insulation or no basement wall insulation.



Basement wall insulation to 600 mm below grade.



BASEMENT WALL DEPTH BELOW GRADE — Average depth ____ m (30)

BASEMENT WALL INSULATION RESISTANCE — R-vALUE of insulation only (Zero (0) if no insulation). ____ Cm2/W (31)

BASEMENT WALL HEAT LOSS FACTOR — Insulation depth below grade ____ m ____ MJ/dayCm2 (32)

BASEMENT WALL BELOW GRADE AREA ____ m2 (33)

BASEMENT WALL MONTHLY LOSS FACTOR

(32) ____ x (33) ____ x 30.3 = ____ MJ/month (34)

I BASEMENT FLOOR LOSSES

BASEMENT FLOOR AREA
Include vertical area at change in floor level. ____ m2 (35)

BASEMENT FLOOR INSULATION R-VALUE
(Zero (0) if no insulation) ____ Cm2/W (36)

MEAN ANNUAL TEMPERATURE DIFFERENCE

BASEMENT SPACE TEMPERATURE ____ C MINUS
ANNUAL MEAN OUTSIDE AIR TEMPERATURE ____ C = ____ C (37)
Obtain from Weather Data Tables
Weather Data Location used ____

MONTHLY BASEMENT FLOOR LOSS

(35) ____ x (37) ____ x 2.62 / (36) ____ + 3.6 = ____ MJ/month (38)

J GROSS MONTHLY HEAT LOSS CALCULATION

LOCATION _____ WEATHER DATA LOCATION _____

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
DEGREE DAY FACTORS Obtain From Weather Data Tables										(50)
MONTHLY ABOVE GRADE LOSS MJ/Month (50) x 42										(51)
MEAN ANNUAL TEMPERATURE DIFFERENCE Enter (37) in each column										(52)
CORRECTION FOR MONTHLY FLUCTUATION	-10.4	-6.0	0.0	+6.0	+10.4	+12.0	+10.4	+6.0	0.0	(53)
MONTHLY TEMPERATURE DIFFERENCE (52) + (53)										(54)
MONTHLY BASEMENT WALL LOSS (54) x 34										(55)
MONTHLY BASEMENT FLOOR LOSS Enter (38) in each column										(56)
GROSS MONTHLY HEAT LOSS MJ/Month Sum of (51) + (55) + (56)										(60)

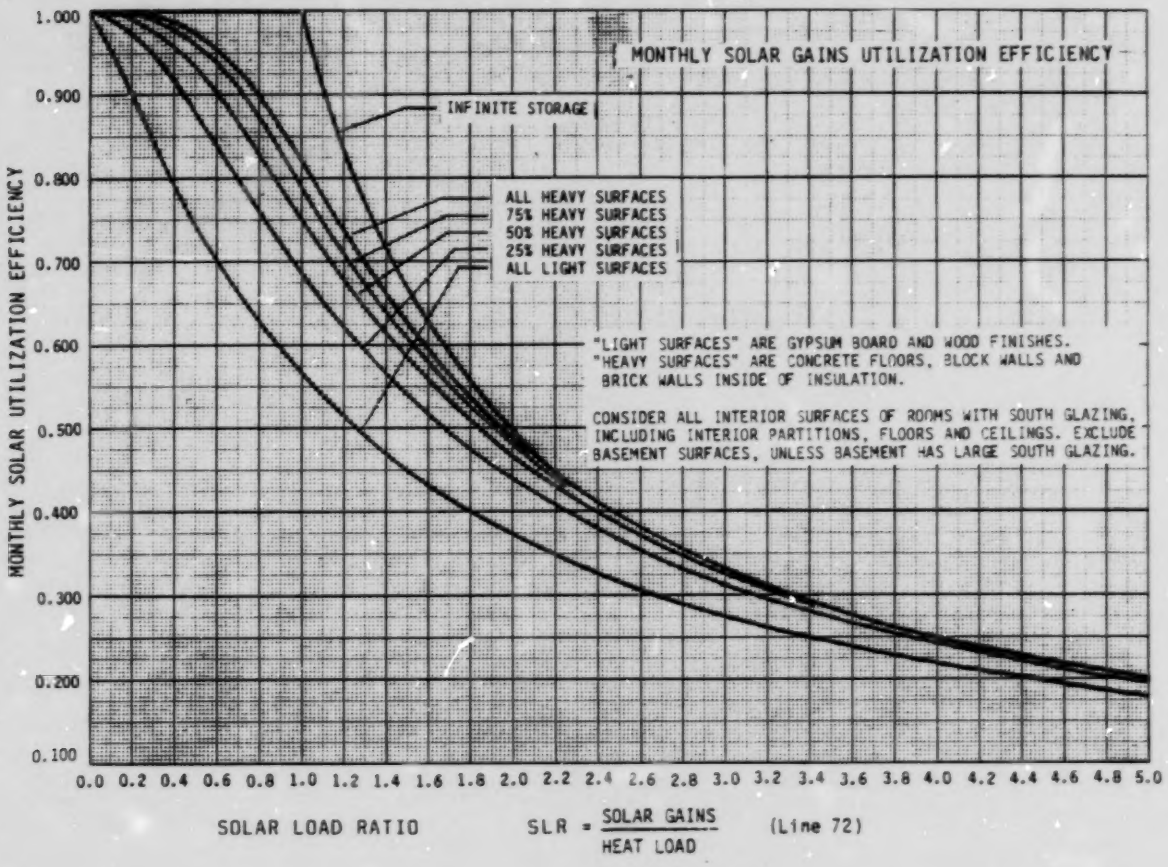
K HEATING ENERGY REQUIREMENT CALCULATION

NET INTERNAL GAINS (MJ/month) (Can be negative) 1800 - 42 x 5.74 = _____ (63)

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
GROSS MONTHLY HEAT LOSS (MJ/month) Enter Numbers of Li. (60)										(64)
MONTHLY NET INTERNAL GAINS Enter Line (63) in each column										(65)
NET MONTHLY HEAT LOSS (MJ/mo) (64) - (65) Enter zero (0) if negative										(66)
MONTHLY SOLAR GAINS RATE (SOUTH) MJ/m2/month from weather tables										(67)
GLAZING TYPE FACTOR 1.1 single glazing (1.0 double glazing) .91 triple glazing .83 quadruple glzg										(68)
CLEAR GLASS AREA (SOUTH) Exclude framing Use 75% of south window area, or measured clear area.										(70)
MONTHLY SOLAR GAINS (67) x (68) x (70) MJ/Month										(71)
SOLAR/LOAD RATIO (71) / (66)										(72)
MONTHLY SOLAR UTILIZATION EFFICIENCY Use graph to the right.										(73)
MONTHLY PASSIVE HEAT (71) x (73) MJ/month										(74)
MONTHLY AUXILIARY HEAT (66) - (74) MJ/month										(75)

ANNUAL AUXILIARY HEAT Add all numbers in (75) _____ MJ/Year

L MONTHLY SOLAR GAINS UTILIZATION EFFICIENCY


MONTHLY SOLAR GAINS UTILIZATION EFFICIENCY
MONTHLY SOLAR UTILIZATION EFFICIENCY
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
INFINITE STORAGE
ALL HEAVY SURFACES
75% HEAVY SURFACES
50% HEAVY SURFACES
25% HEAVY SURFACES
ALL LIGHT SURFACES
"LIGHT SURFACES" ARE GYPSUM BOARD AND WOOD FINISHES.
"HEAVY SURFACES" ARE CONCRETE FLOORS, BLOCK WALLS AND BRICK WALLS INSIDE OF INSULATION.
CONSIDER ALL INTERIOR SURFACES OF ROOMS WITH SOUTH GLAZING, INCLUDING INTERIOR PARTITIONS, FLOORS AND CEILINGS. EXCLUDE BASEMENT SURFACES, UNLESS BASEMENT HAS LARGE SOUTH GLAZING.
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8 5.0
SOLAR LOAD RATIO

$$SLR = \frac{\text{SOLAR GAINS}}{\text{HEAT LOAD}} \quad \text{(Line 72)}$$

NOTE:

A room has six surfaces: four walls, floor and ceiling. The floor must be given extra weight because most of the time the rays of the sun first reach the floor and are then reflected to the remaining surfaces. Count the floor as three surfaces for a total of eight surfaces in the room. The percentage of heavy surfaces is then estimated by counting the number of heavy surfaces and dividing that number by eight. A room with a concrete floor will have about 40% heavy surfaces. If the southern portion of the house consists of 2 rooms with substantial south glass, then there would be 2 x 8 = 16 surfaces to consider. A feature brick wall between the two rooms would count as two heavy surfaces, concrete floor in one of the rooms would add another three heavy surfaces for a total of five heavy surfaces in 16 or 30%.

PART THREE: DETAILED CALCULATIONS

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Long Form Calculation Forms

Heat Storage Calculation Forms

PART THREE: DETAILED CALCULATIONS

Part Three provides a detailed calculation procedure for more precise determination of passive solar gain, heat loss, required heating and auxiliary heating requirements. The procedure enables an estimate of heat storage and determines whether the temperature swing is within acceptable limits.

3.1 INTRODUCTION

The purpose of this detailed calculation procedure is to obtain a more accurate estimate of heat loss and to include a broader range of passive solar gain factors. This approach helps to more accurately determine the benefits of specific low energy/passive solar features for new and existing housing. The procedure also takes into account occupant comfort by means of estimates of maximum temperature swing in south living spaces during sunny winter days.

Because the procedure requires more calculation effort, its best use is for evaluating housing designs that could be extensively repeated, and where high accuracy is necessary. The procedure is very useful to measure the impact of basic types of passive solar features such as attached unheated sun spaces, heavy construction, effects of off-south orientation and implications of shading.

In developing the manual, a balance had to be struck between high accuracy, convenience and simplicity for the user. Prediction of heating energy for one specific residence cannot be expected to be more accurate than within 90%, even with the most detailed methods. This is due to the variation in living habits of the occupants and minor differences between the actual construction details and those used in the calculations. Air infiltration, soil conductivity and water table effects on basement heating losses are particularly difficult to estimate. The

savings in energy used due to energy conservation measures, however, can be determined much more accurately than the total amount of the heating energy. Test calculations indicate that the following detailed calculation procedures can be expected to provide results within 10% for estimating annual heating energy and within 2-3% in determining the effects of more insulation, changes in glazing area, etc. The notes explain how the calculation can be refined further, particularly regarding additional solar gains through other than south glazing and inclusion of shading effects of overhangs and other obstructions.

3.2 HOW THE DETAILED CALCULATIONS DIFFER FROM SHORT FORM

The long form calculations differ from those provided in the short form procedures in a number of specific ways. These provide for greater precision and accuracy with respect to heat loss, passive solar gain, and determination of temperature swing. The long form calculations include:

- Provision in the calculation forms for four different compositions for windows, walls, ceilings, doors and basement walls. These enable variations in these elements within a single house design to be taken into account.

- Consideration of thermal effects of studs in walls and joists in ceilings, the use of resistance values for air films, and a full range of construction materials to provide a more accurate composite R factor for walls, ceilings, doors and basement walls.

- Recognition of the need for estimating the thermal performance of special portions of the exterior skin in the calculations (i.e. wall plates, joist headers, cantilevered floor areas).

- Provision for considering attached unheated spaces in the total above grade loss co-efficient. These include attached garages and porches.

- Provision for separate calculations for available/required heat storage capacity. These include estimates of stored heat, solar and air swing storage, and required storage to keep temperature swings within the desired range.

- Provision for calculations and related graphs to estimate effects of shading and orientation off-true-south.

- Explanations on how to modify calculations to determine contribution of solar gain through glazing on other than south walls, and through insulated portions of the building envelope.

These features, although they require additional effort in computation, provide the higher level of accuracy mentioned above.

3.3 LIST OF LONG FORM CALCULATION PROCEDURES

The procedure for calculating heat loss and required auxiliary heating is carried out on 13 forms which have related explanatory notes included. These forms are:

- L-1: A - window losses,
- L-2: B - wall losses,
- L-3: C - ceiling losses,
- L-4: D - door losses,
  E - special portions of exterior skin losses,
- L-5 F - infiltration losses,
- L-6: G - basement wall above grade losses,

- L-7: H - basement wall below grade losses,
- L-8: I - basement floor losses,
- L-9: J - adjustment for attached unheated spaces,
- L-10: K - total above grade loss co-efficient,
- L-11: L - gross monthly heat loss calculations,
- L-12: M - heating energy requirements calculations,
- L-13: N - graph of monthly solar gains utilization efficiency.

A set of blank forms is included at the end of this section for convenient copying.

3.4 HEAT STORAGE CAPACITY CALCULATIONS

This second set of detailed calculations deals specifically with estimating adequacy of thermal storage and extent of temperature swing.

3.4.1 Introduction

The purpose of these calculations for specific house designs is to determine whether the temperature swing in rooms with south glass will be controlled within design limits during sunny winter days. The calculations thus estimate whether the temperature increase due to build-up of passive solar gains does not exceed a pre-selected figure in the range of 3-7 C degrees.

This calculation is important to confirm whether the south glazing and related storage materials are in balance to prevent the discomfort of overheating and resulting waste of solar gain due to venting to the outside.

3.4.2 Calculation Procedures

The following forms are used:

- HS-1: A - factors for solar storage and air temperature swing,
- HS-2: B - solar storage (without temperature swing). This computes solar storage within rooms with south glazing,
- HS-3: C - solar air swing storage. This form enables computation of the coupling effect between spaces with south glazing and those without.
- HS-4: D - required storage. This includes comparison of total solar gains to total losses to determine required storage so that temperature swing in rooms with south glazing is within acceptable limits.

These calculations permit a check on the selection of design details such as glazing type and area, and weight of construction materials in rooms with south glazing to ensure acceptable temperature swings.

A set of these forms is included for photocopying.

3.5 USING THE DETAILED CALCULATION PROCEDURES

As indicated above, calculation procedures (excluding detailed shading calculations which are done separately) are of two types:

- heat loss and auxiliary heat requirements (including the effect of passive solar gain); and
- available/required heat storage capacity.

Heat loss and auxiliary heat requirements calculations can be done

first because they provide input (infiltration rate) to the available/required heat storage capacity calculations. This procedure is satisfactory if the designer is confident that temperature swing is acceptable and if the heat storage capacity calculations are to serve merely to confirm this.

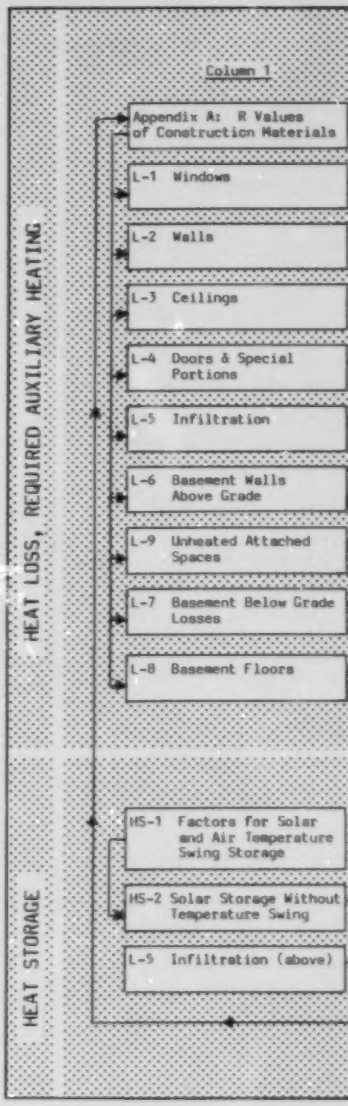
However, if a house design is being modified to the extent that the designer is no longer certain that adequate heat storage capacity is being provided, it may be preferable to carry out that set of calculations first in order to make the necessary modifications to either provide adequate storage or reduce glazing in order to limit temperature swing to an acceptable level. These modifications may in turn affect the heat loss and auxiliary heating requirements calculations.

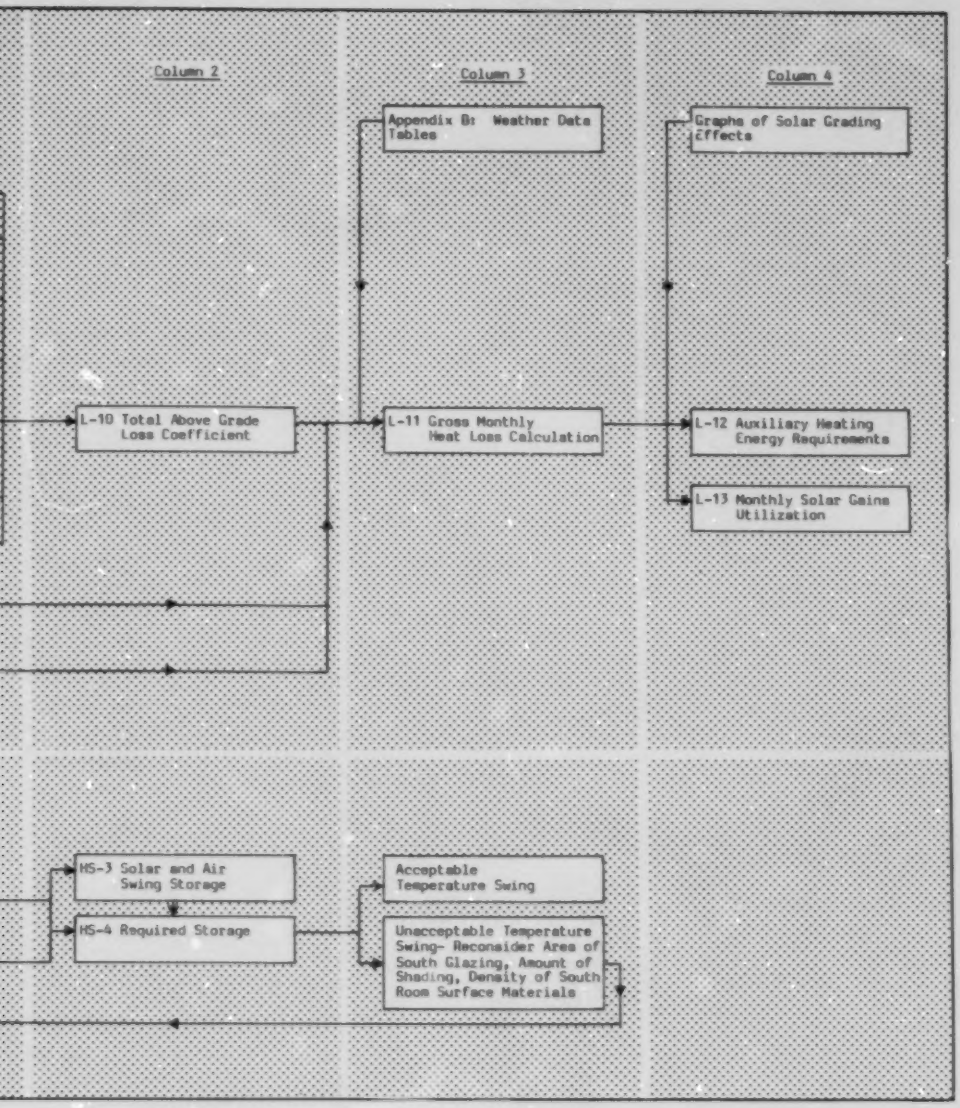
3.5.1 Heat Loss and Auxiliary Heating Requirements

The following steps are illustrated in Figure 3.1, the flow chart for detailed calculations:

- in column 1, carry out calculations on forms L-1 to L-9 inclusive, selecting R values for construction materials from Appendix A. The results will provide individual heat loss co-efficients and basement heat loss;
- in column 2, sum the heat loss co-efficients to get the total heat loss co-efficient (form L-10).
- in column 3, using the weather data provided in Appendix B, use the total above grade heat loss co-efficients and the basement heat losses to compute the gross monthly heat loss (form L-11).
- finally, in column 4, with the use of graphs for solar shading and monthly solar gains utilization efficiency (form L-13), compute auxiliary heating requirements (form L-12).

Figure 3.1
Flow Chart for Detailed


HEAT LOSS, REQUIRED AUXILIARY HEATING
HEAT STORAGE
Column 1
Appendix A: R Values of Construction Materials
L-1 Windows
L-2 Walls
L-3 Ceilings
L-4 Doors & Special Portions
L-5 Infiltration
L-6 Basement Walls Above Grade
L-9 Unheated Attached Spaces
L-7 Basement Below Grade Losses
L-8 Basement Floors
HS-1 Factors for Solar and Air Temperature Swing Storage
HS-2 Solar Storage Without Temperature Swing
L-5 Infiltration (above)


Column 2
Column 3
Column 4
Appendix B: Weather Data Tables
Graphs of Solar Grading Effects
L-10 Total Above Grade Loss Coefficient
L-11 Gross Monthly Heat Loss Calculation
L-12 Auxiliary Heating Energy Requirements
L-13 Monthly Solar Gains Utilization
MS-3 Solar and Air Swing Storage
MS-4 Required Storage
Acceptable Temperature Swing
Unacceptable Temperature Swing- Reconsider Area of South Glazing, Amount of Shading, Density of South Room Surface Materials

3.5.2 Heat Storage Capacity Calculations

The following steps are illustrated in Figure 3.1 and deal with available/required heat storage:

- in column 1, calculate solar storage and temperature swing using form HS-2 taking factors from HS-1. Note the need for the infiltration rate calculated on form L-5 above.

- in column 2, compute available air swing storage and total available storage on form HS-3. Add the infiltration factor to compute the required storage on form HS-4. If the temperature swing is acceptable, no further work need be done.

- in column 3, if the temperature swing is too high, make modifications to the glazed area, and/or extent of shading and/or weight of construction. Make the necessary modifications, selecting the new (if necessary) R values from Appendix A, and recalculate the available/required heat storage.

3.5.3 Alternative Procedure

As indicated above, if the designer has made major changes to factors affecting solar gain then it is logical to perform the available/required heat storage calculations first. If the temperature swing is too high, then design/construction changes can be made without having to redo the heat loss and auxiliary heating requirements. Note that form L-5 must be used to determine the infiltration factor to carry out the remainder of the heat storage calculations.

When the designer is satisfied that he has suitable features to control temperature swing, he can then proceed to perform more extensive calculations on heat loss and required auxiliary heating.

3.6 SHADING EFFECTS

Preventing the sun's rays from striking the building envelope during winter will reduce passive solar gain, particularly if window areas are involved. This section discusses three types of shading and provides means for computing their effects:

- overhang shading;
- recessed windows;
- shading by tall objects (including projecting walls).

3.6.1 Overhang Shading

The graphs (Figure 3.2) are in the form of factors to be applied to the monthly solar radiation gains and therefore represent the true net effect of the overhang for a south facing window. The length of the overhang in the graphs is unity. Therefore the window dimensions have to be drawn on the graph as proportions of the overhang length. (See example). Once the top and the bottom of the window are located on the graph, then the monthly factor can be estimated as the average value of the monthly curve over the window dimension. Good accuracy can be obtained by reading the graph at the two quarter points of the window (centre of the upper half and centre of the lower half of the window) and then averaging the two readings.

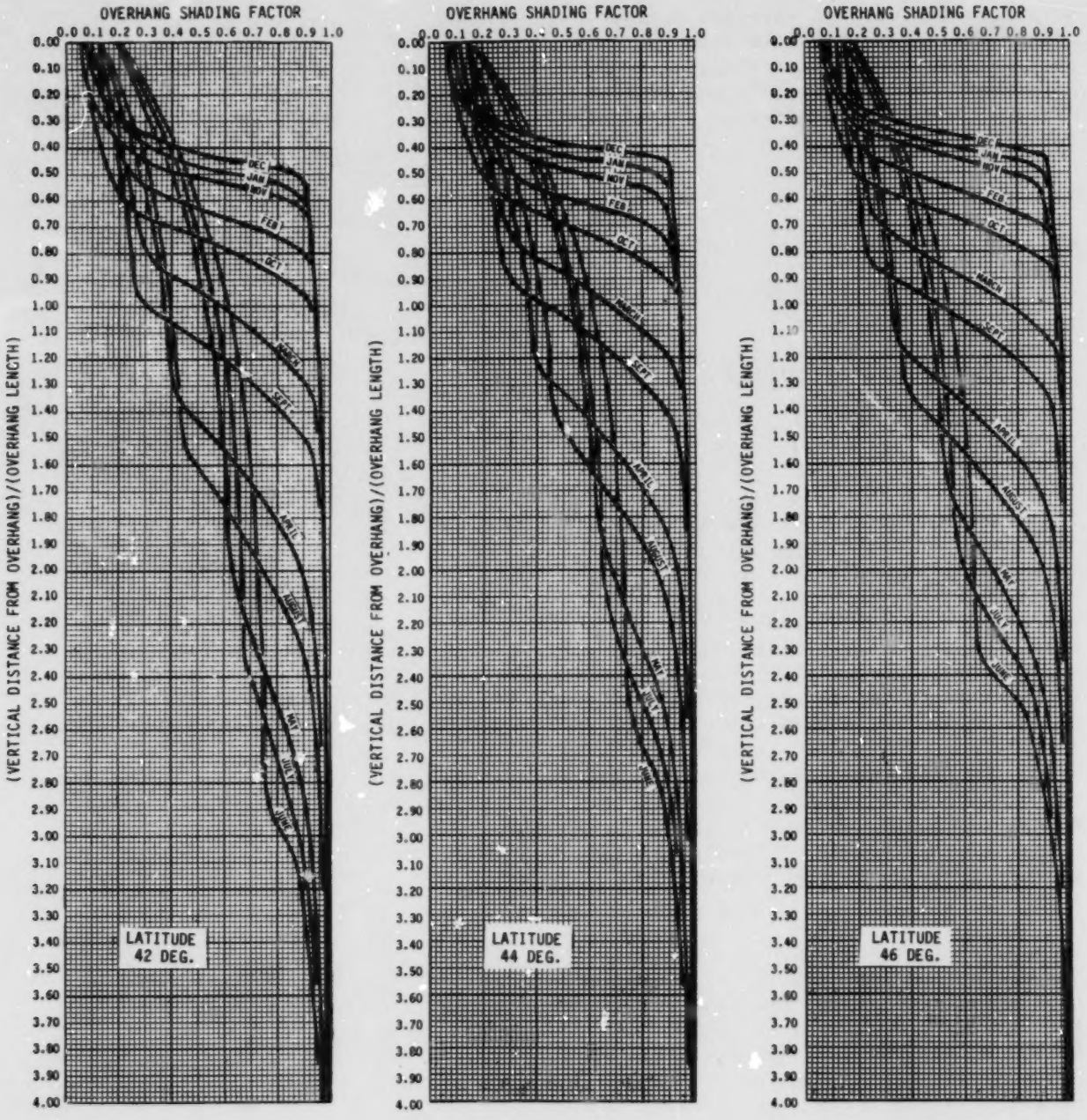
This type of presentation gives a good immediate visual indication of the overhang effect and allows the handling of the varying proportions of the window head and the window height dimensions in a simple and visual manner. For a more detailed discussion of the overhang effects see the following notes on the Derivation of Overhang Graphs.

Example

Determine the monthly overhang effects for the following house window facing south. See Figure 3.3, Table 3.1.

090051

Figure 3.2
Overhang Shading Factors

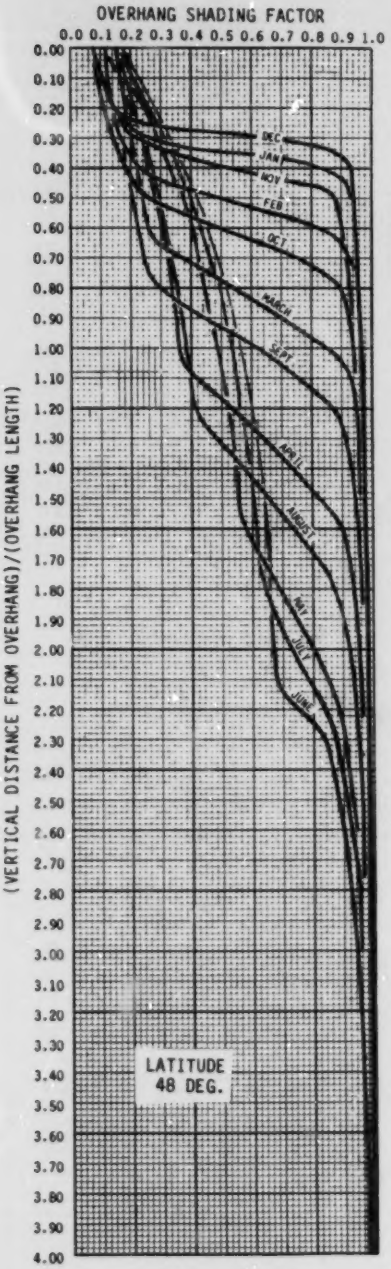


USE FOR: SIMCOE
WINDSOR

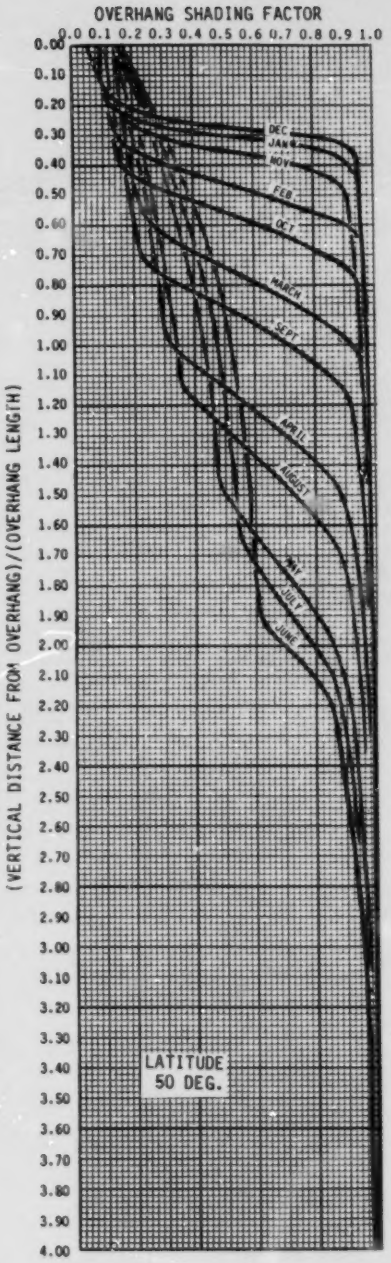
USE FOR: KINGSTON
LONDON
MUSKOKA
TORONTO

USE FOR: GORE BAY
NORTH BAY
OTTAWA
SAULT STE. MARIE
SUDBURY

Figure 3.2 (continued)
Overhang Shading Factors



USE FOR: ATIKOKAN
EARLTON
THUNDER BAY
TIMMINS



USE FOR: GERALDTON
KAPUSKASING
KENORA
SIOUX LOOKOUT

000053

Location: - Earlton, Ontario

Latitude: - 47.7 degrees north

Overhang Length: - 630 mm

Vertical distance from tip of overhang to top of glass - 300 mm

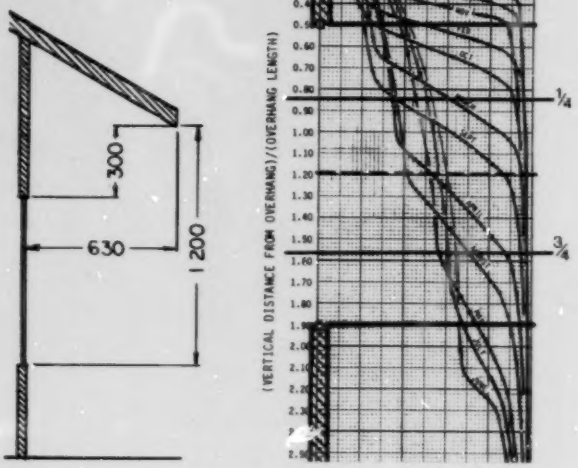
Vertical distance from tip of overhang to bottom of glass: - 1200 mm.

Proportionate distance of overhang to top of window - $\frac{300}{630}$ = 0·476

Proportionate distance of overhang to bottom of window - $\frac{1200}{630}$ = 1·905

Nearest graph latitude: 48 degrees.
Refer to figure 3.3 and Table 3.1.

Figure 3.3
Overhang Shading Example



Notes on the Derivation of Overhang Graphs

As explained in Section 1.1.2, solar gains through glazing can be divided into three components:

- beam radiation gains;
- sky diffuse radiation gains;
- ground reflected radiation gains.

The overhang has an effect only on the first two categories of the solar gains. The third category, ground reflected radiation gains, are not influenced by the overhang, except for the case where the underside of the overhang has high solar reflectivity (i.e. light colour) and therefore may increase the ground reflected radiation gains by the amount re-reflected from the underside of the overhang. It is preferable therefore to use dark colours for the underside of the overhang, or to use open inclined slat type or sloping solid overhangs that do not "see" much of the ground reflected radiation.

The purpose of the overhang is to

TABLE 3.1

MONTHLY OVERHANG SHADING EXAMPLE

	1/4 READING	3/4 READING	AVERAGE
January	.96	.98	.97
February	.96	.98	.97
March	.60	.98	.79
April	.34	.87	.60
May	.45	.56	.50
June	.53	.64	.59
July	.50	.61	.56
August	.36	.70	.53
September	.35	.95	.65
October	.91	.98	.94
November	.94	.98	.96
December	.96	.98	.97

reduce the solar gains in summer. The net effect of the overhang on summer solar gains in Ontario latitudes is not as great as might appear from the observation that the south window is fully shaded by the overhang in summer. The reflection properties of glazing are such that with high summer sun the glass itself excludes most of the beam radiation gains. While in January the beam radiation gains may constitute 82% of the total solar gains, in July they amount to only 32% for double glazing without an overhang. Therefore a typical overhang cannot eliminate more than some 40% of the summer solar gains.

To properly assess the monthly overhang effects on the solar gains, one has to consider not only the solar geometry and the view angle factors for diffuse radiation, but also the monthly relative proportions of the three categories of solar gains that may be typical for a given location. The added complication is the non-uniformity of the overhang effect over the height of the glass. The portions nearer the overhang are shaded more than the portions that are further from the overhang.

The shading graphs are prepared for latitudes of 42, 44, 46, 48 and 50 degrees. They are derived from hourly calculations of solar gains for various vertical elements of the glazing, both with and without the overhang. The monthly (10 year average) solar data of an actual Ontario location closest to a particular latitude step is used for the relative proportions of the three categories of the solar radiation gains. A non-reflecting underside of the overhang is assumed.

Some of the published methods for the calculation of the overhang shading effects are rather simplistic and consider beam radiation only. Such methods can lead to substantial errors.

3.6.2 Recessing of Windows

The walls may be quite thick in a

superinsulated house. In a house with window openings in such thick walls, a substantial portion of the solar gains could be shaded out. All three categories of radiation gains are affected by window recessing, namely beam, sky diffuse and ground reflected radiation.

Both the outdoor portion and the indoor portion of the window recess contribute to the shading. Due to the reflectivity characteristics of glass at low angles of incidence however, the indoor portion contributes substantially less so that only the outdoor portion needs to be considered in a practical case. The indoor portion can be said to reduce the effective absorptivity for solar energy by the window opening in the same manner as anything else that makes the window appear less dark when viewed from the outside.

Shading due to window recessing varies with latitude, time of the year and the width-to-height ratio of the window. The most important factor is the ratio of the depth of the recess to the window dimension. The following graphs (Figure 3.4) are obtained from hourly computer calculations over the year for different latitudes. A square window is assumed (height equals width). The finish of the recess is assumed to have low reflectivity. The factor to be applied to solar gain is plotted against the ratio of the recess depth to the window dimension (width or height, since the window is square).

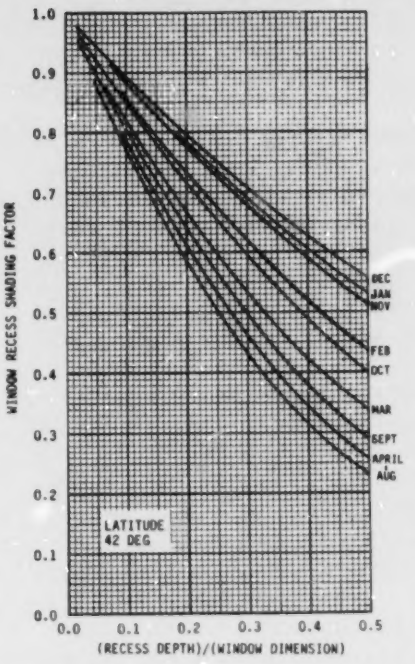
Example of Window
Recessing Effect

South window of a house located in Windsor, Ontario (Latitude 42.27 deg.) is recessed 300 mm and the window dimensions are 1000 mm height and width, (Figure 3.5).

Recess depth to window dimension ratio is 300/1000 = 0.3

Graph for Latitude 42 degrees gives the following window recess shading factors (turn to page 3-16):

Figure 3.4
Window Recess Shading Factors



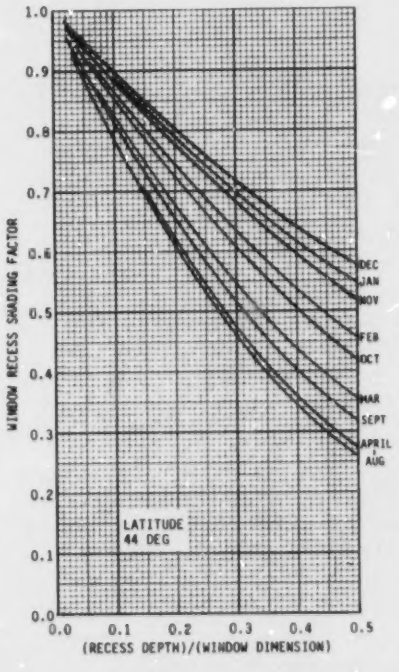
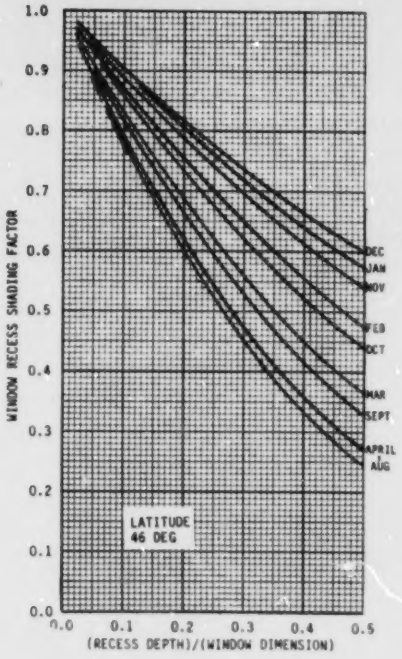
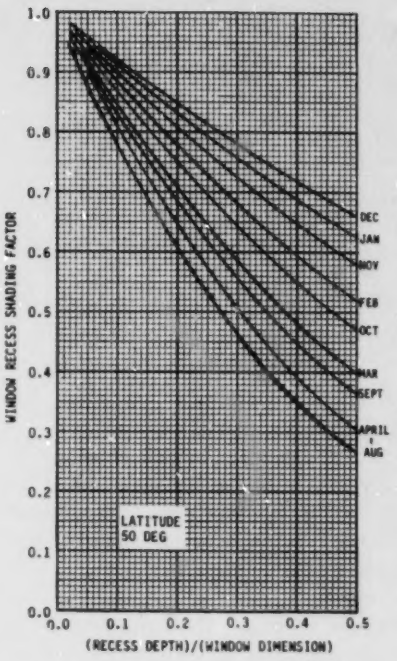


Figure 3.4 (continued)
Window Recess Shading Factors





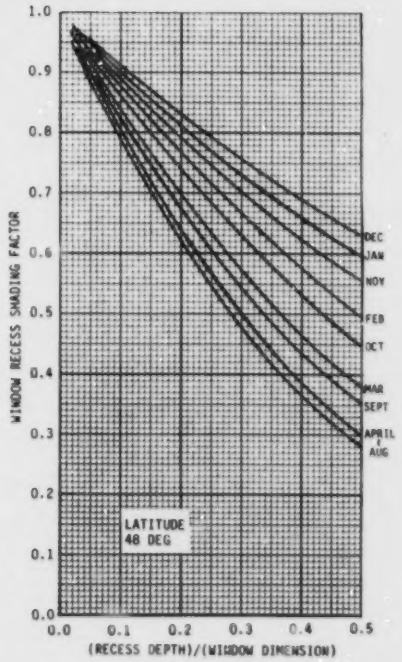
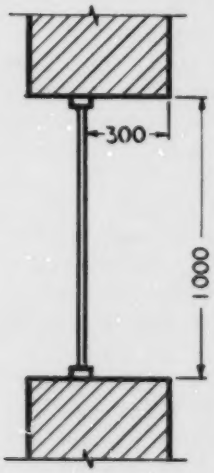


Figure 3.5
Window Recess Example



000057

September	-	0.495
October	-	0.595
November	-	0.677
December	-	0.705
January	-	0.690
February	-	0.620
March	-	0.535
April	-	0.450
May	-	0.450

3.6.3 Shading by Tall Objects

Shading by tall objects in front of or to the side of a window has an effect on all three solar gain components, namely beam radiation, sky diffuse radiation and ground reflected radiation. Since there are many possible configurations of such objects with the glazing, only a general discussion of the approximate shading effects and some "rules of thumb" can be given.

The effect of such objects on ground reflected and sky diffuse radiation gains is constant at all times of the year. The beam radiation shading varies with time due to the sideways (azimuthal) motion of the sun.

If the obstructing object is in front of the window, close to and much larger than the window, such as a tree, it may shade the window at all times. Bare branches of a tree can shade out 20 to 40% of the solar gains. If the object is solid, relatively slender and close to the window then it will shade out its projected area on the window at all times, even though the shadow will move and will shade different parts of the window at different times.

The more difficult cases arise with objects that are at a distance or at the side so that they cast a shadow on the

window only during a portion of the day. One general rule of thumb for dealing with such cases is shown in Figures 3.6, 3.7 and can be described as follows.

On a plan showing the size and the position of the obstruction as well as the window, draw a line from the centre of the window and at right angle to the window. Draw in two lines at 50 degrees from this line, again originating at the centre of the window. The two lines delineate the "100 degree angle of view" of the window. Such a restricted angle of view compensates for the lower solar gains at shallow angles of incidence.

Any obstruction within the angle of view will shade the window. It may be noted that obstructions outside of the angle of view will shade the solar gains by less than 5%. The shading angle is equal to the angle between the lines from the centre of the window to the edges of the obstruction. If only one side of the obstruction is within the angle of view, then measure only to the edge of the angle of view. Since a 100 degree angle of view is being considered, the shading angle also equals the shading fraction in %. To express the shading fraction as a fraction, divide the shading angle by 100. The factor to be applied to the solar gains equals unity minus the shading fraction. Shading fractions of several obstructions may be added together in determining the overall solar gains factor. For details of this rule of thumb see the two examples below.

In Figure 3.6 the obstruction is entirely within the "angle of view". Therefore angle subtended by the obstruction represents the shaded fraction:

$$\frac{14}{100} = 0.4$$

The factor to be applied to the solar gains is 1 - 0.14 = 0.86.

Figure 3.6
Obstruction Entirely Within Angle of View

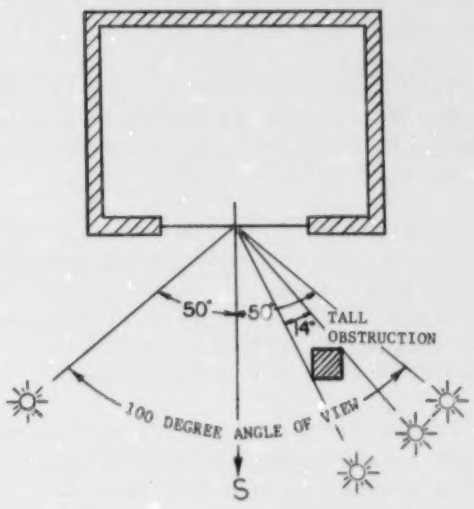
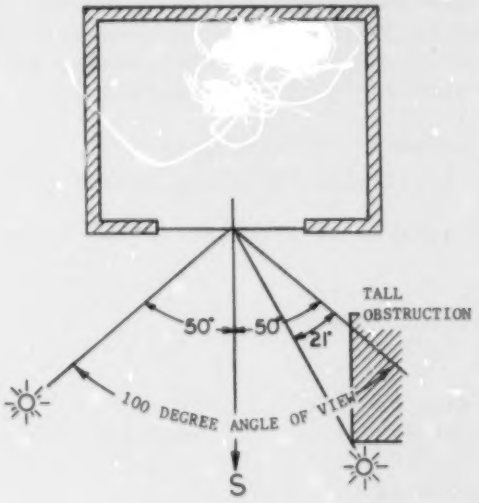


Figure 3.7
Obstruction Partly Within Angle of View



In Figure 3.7 the obstruction is partially within the "angle of view". Measure the shaded fraction from side of angle of view to edge of obstruction:

$$\text{Shaded fraction is } \frac{21}{100} = 0.21$$

The factor to be applied to the solar gains is 1 - 0.21 = 0.79.

Note that this case can be treated as a projected wall at the side of the window. The answer from the graph for this case is 0.78.

A fairly common case of shading by tall objects is the case of an adjacent wall projecting out at right angles to the window. If such a wall is long and is very close to the window it will shade out 50% of the solar gains.

Figure 3.8 gives the factor to be applied to the solar gains to account for the shading by a projecting wall near the window. The graph is used in a similar manner to the graphs for the overhang. Although the graph does in fact vary with latitude and the time of the year, the variation is less than for the overhang shading. In order to simplify the procedure an average curve is given. Refer to the following sample calculation for further details.

Example of Shading by
Projecting Wall Near Window

This example is illustrated in Figure 3.9.

Length of Projecting
Wall A: 3000 mm

Distance to Near
Side Window B: 1200 mm

Distance to Far
Side of Window: 2000 mm

Proportional Distance
to Near Edge: $\frac{B}{A} = \frac{1200}{3000} = 0.4$

Figure 3.8
Projecting Wall Shading Factors

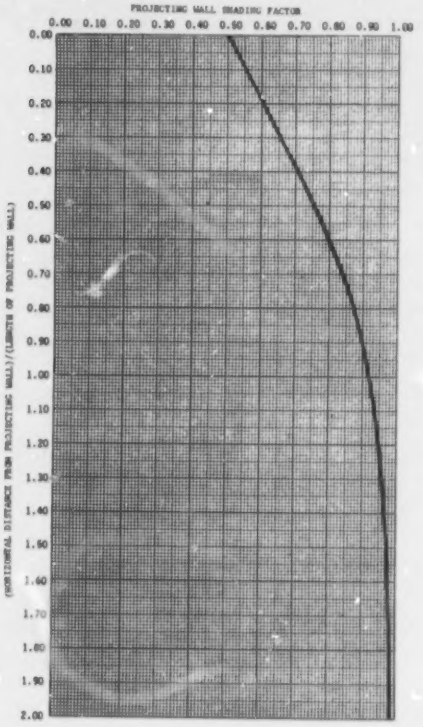
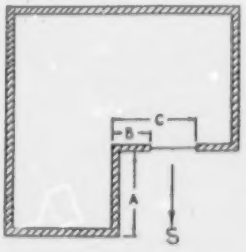
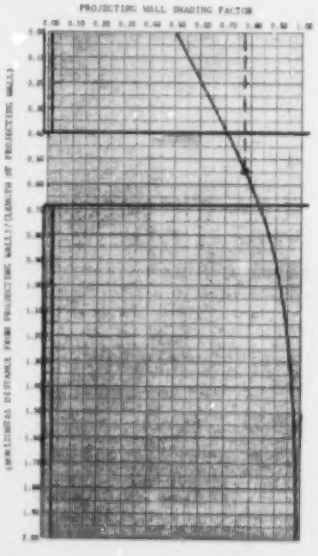


Figure 3.9
Example of Shading by Projecting Wall





Proportional Distance to Far Edge: $\frac{C}{A} = \frac{2000}{3000} = 0.67$

The projecting wall shading factor is taken as the average of the two intersections of the proportional distances and the curve in the graph in Figure 3.9. This value is read from the horizontal axis and is 0.78.

3.7 EFFECTS OF OFF-TRUE-SOUTH ORIENTATION

It is sometimes not possible to orient the house exactly south. In fact the optimum orientation is 5 to 10 degrees east of south. This is explained earlier in terms of early warming of the house (Section 1.3.1). It is also indicated by hourly computer models that account for the thermal storage effects, the hourly variation in internal gains and the matching between the heating demand and the solar gains.

Figure 3.10 indicates the monthly effect on the solar gains for the orientations off true south. The effect varies with latitude. The graph however, indicates the average effect for latitudes 42 to 50, again using the actual Ontario solar data. The northern locations are affected more by off-south orientation, although the maximum latitude effect generally does not exceed the month-to-month variation indicated on the graph.

The overall annual effect of the off-south orientation on the auxiliary fuel consumption of a house depends on many factors, eg. insulation levels, airtightness, proportion of south glazing area to floor area, etc. The auxiliary fuel requirements of two houses with different insulation and airtightness levels have been simulated with the hourly computer model using Toronto weather data. The houses have a glazing area on their south elevations of about 9% of the total floor area. The "better" house consumes about 65% of the heating energy of the "poorer" house when both are oriented true south. The results are presented in Figure 3.11.

It can be seen in the graph that the better house is more sensitive to the off-south orientation. The lesser

Figure 3.10
Solar Gain Factors for Off-True-South Orientation

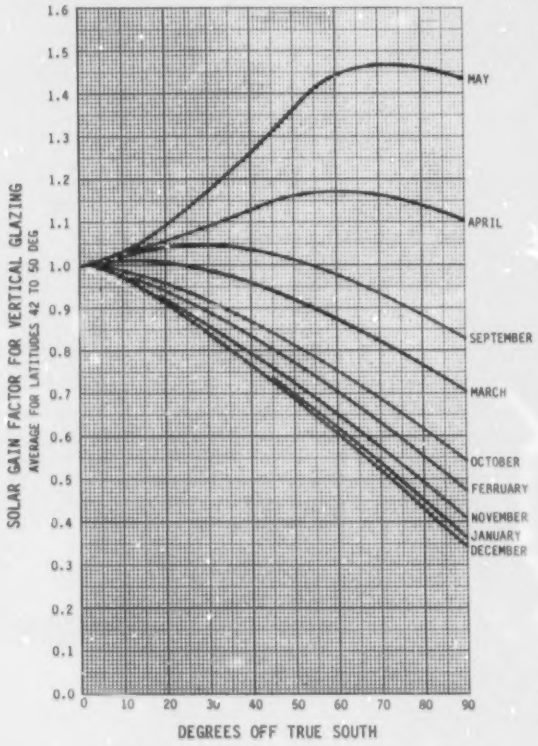
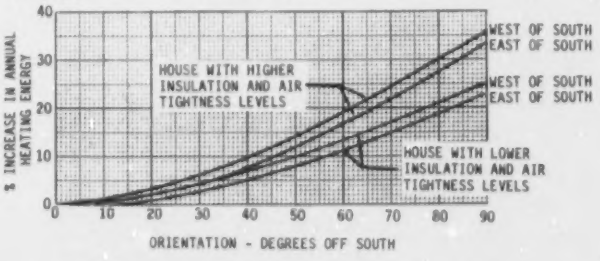


Figure 3.11
Percent Increase in Annual Heating Energy for Orientation Off True South



FOR HOUSES WITH GLASS AREA ON THE SOUTH ELEVATION EXCEEDING 5-6% OF TOTAL FLOOR AREA

000961

detrimental effect of the easterly vs. westerly orientations can be also noted. It must be appreciated that the results can be substantially different for other specific houses and locations. They should be calculated individually using the monthly shading graphs and the monthly energy balances as determined in the Heating Energy Requirement Calculation (form L-12).

PROJECT NAME _____
LOCATION _____

*** HEAT LOSS CALCULATIONS ***

These calculations are designed specifically for the determination of the average heating energy consumption and must NOT be used to size furnaces or other heating equipment. Window losses, infiltration losses and basement losses are lower than the recommended values for the calculation of the maximum instantaneous load for equipment sizing.

All units are metric, including insulation R values.

A WINDOW LOSSES

WINDOW TYPE	A	B	C	D
Description				

WINDOW AREA (m2) Window dimensions to include frames, ie. use gross wall opening dimensions. Include sliding glass patio doors, basement windows and windows from house to unheated attached spaces, but NOT windows from such unheated attached spaces to outdoors.

(1A)	(1B)	(1C)	(1D)

WINDOW RESISTANCE (Cm2/W)

See Note 1 for air spaces which are smaller than 12mm, for night shutters, and for special glazings.

Suggested Values:
.22 for single glazing
.41 for double glazing
.61 for triple glazing

(2A)	(2B)	(2C)	(2D)

WINDOW LOSS COEFFICIENTS (W/C)

Line 1 / Line 2
E.g. (1A) / (2A) = (3A)

(3A)	(3B)	(3C)	(3D)

TOTAL WINDOW LOSS COEFFICIENT (3A) + (3B) + (3C) + (3D) = (4) W/C

---

1. ASHRAE window resistance values are appropriate only for estimation of max. load, as extreme weather conditions are assumed. They should not be used in monthly energy calculations. If calculated window resistance is to be used for special glazings, then use .10 for the exterior air film resistance and .12 for the interior air film resistance.

   Resistance values tabulated in the calculation form are for glazing with 12 mm air spaces. For each 6 mm air space deduct .05. Tabulated values are for windows with wood framing taking up 20-25% of the gross window area. If your windows differ significantly then use correction factors for framing types as follows:

   Window metal frame w/o thermal break .79

   Sliding door metal frame w/o thermal break .86

   Wood frame 40% of gross window area 1.12

   If night shutters are used with resistance equal to R_S (.5 to 2.0 are typical values), multiply glass resistance by

$$\frac{R_{GLASS} + R_S}{R_{GLASS} + (R_S \times H/24)}$$

   Where H is number of hours/day without night shutters.

B WALL LOSSES

WALL TYPE	A	B	C	D
Description				

WALL AREA (m2) Gross wall area minus window area and minus door area. Include wall to attached unheated spaces.

NOTE: Use inside house dimensions to determine wall area with standard construction. For wall with internal mass, measure wall area at midpoint of insulation if possible, otherwise use outside wall dimensions.

(5A)	(5B)	(5C)	(5D)

WALL RESISTANCE (Cm2/W)

Calculate by summing resistances of wall layers and air films. Use values given in Thermal Resistance Value tables. (Multiply Imperial R values by .1761 to convert them to metric.)

Exterior Film	.10	.10	.10	.10
Exterior Finish				
Sheathing Matrls (.08) [1]				
Insulation A [2]				
Air Space (.17)				
Insulation B [2]				
Interior Materials				
Interior Finish (.08) [1]				
Interior Film	.12	.12	.12	.12
SUM=	(6A)	(6B)	(6C)	(6D)

WALL LOSS COEFF. W/C

(7A)	(7B)	(7C)	(7D)

Line 5/Line 6 E.g. (5A)/(6A)=(7A)

TOTAL WALL LOSS COEFFICIENT (7A) + (7B) + (7C) + (7D) = (8) W/C

[1] .08 is the resistance for 9mm plywood or 13mm gypsum board. For other materials see the Thermal Resistance Value tables.

[2] See Note No. 2 regarding adjustment for wood studs in wall.

---

2. If insulation (+ air space if any) is in stud space, reduce insulation (+ air space) resistance to

$$\frac{1}{.19 + .85/R_{\text{Insulation and air space}}}$$

The above is correct for the standard stud wall.

For a wall with R 2.11 insulation and 400 mm stud spacing, insulation is reduced to R 1.69 (reduction of 20%).

For other stud walls use

$$\frac{1}{F/(\text{stud depth mm} \times 0.0087) + (1-F)/R_{\text{Insulation}}}$$

Where F = fraction of wall area taken up by wood framing or joists.

C CEILING LOSSES

CEILING TYPE Description	A	B	C	D
CEILING AREA (m2)	9A	9B	9C	9D

CEILING RESISTANCE (Cm2/W) Calculate similar to Wall Resistance.
Note No. 3 applies to ceiling joists also.

	A	B	C	D
Exterior Film	.10	.10	.10	.10
Exterior Finish (.08)				
Exterior Materials				
Insulation A				
Air Space (.15)				
Insulation B				
Interior Materials				
Interior Finish (.08)				
Interior Film	.11	.11	.11	.11
SUM =	10A	10B	10C	10D

CEILING LOSS COEFF. W/C

A	B	C	D
11A	11B	11C	11D

Line 9/Line 10
E.g. 9A ÷ 10A = 11A

TOTAL CEILING LOSS COEFFICIENT 11A + 11B + 11C + 11D = 12 W/C

---

3. If insulation (+ air space if any) is in joist space, reduce insulation (+ air space) resistance to

$$\frac{1}{F/(\text{stud depth mm} \times 0.0087) + (1-F)/R_{\text{Insulation}}}$$

Where F = fraction of wall area taken up by wood framing or joists.

D DOOR LOSSES

	A	B	C	D
DOOR TYPE Description				
DOOR AREA (m2) Include doors to attached unheated spaces.	13A	13B	13C	13D
DOOR RESISTANCE (Cm2/W) Suggested Values: 35mm Wood with metal storm .63; 45mm Steel with urethane core .44	14A	14B	14C	14D
DOOR LOSS COEFF. (W/C) Line 13/Line 14 E.g. 13A/14A=15A	15A	15B	15C	15D

TOTAL DOOR LOSS COEFFICIENT 15A + 15B + 15C + 15C = 16 W/C

E SPECIAL PORTIONS OF EXTERIOR SKIN LOSSES

Use for wall plates, joist header areas, overhung floor areas and other wall constructions if substantially different from main wall construction.

	A	B	C	D
SPECIAL PORTION TYPE Description				
SPECIAL PORTION AREA (m2)	17A	17B	17C	17D
SPECIAL PORTION RESISTANCE (Cm2/W) Calculate similiar to Wall Resistance.				
Exterior Film	.10	.10	.10	.10
Interior Film	.12	.12	.12	.12
SUM =	18A	18B	18C	18D
LOSS COEFFICIENTS (W/C) Line 17/Line 18 E.g. 17A/18A=19A	19A	19B	19C	19D

TOTAL SPECIAL PORTION LOSS COEFFICIENT 19A+19B+19C+19D= 20 W/C

F INFILTRATION LOSSES

AIR CHANGE RATE Use measured infiltration AIR CHANGES/HR or the following estimated values:

-Older house (pre 1976)	1.0+ AC/hr
-Conventional construction (fossil fuel)	0.5 AC/hr
-Carefully constructed fossil fuel or average electrically heated house	0.3 AC/hr
-Super energy efficient air tight construction	0.05 - 0.1 AC/hr

Use .3 for the last case if there is no forced ventilation with heat exchanger.

AC/hr (21)

See Note No. 4 regarding minimum ventilation rates and correlation of infiltration to pressurization tests.

HEATED VOLUME Include semi-basement rooms that have walk out doors or large windows. Include 1/2 volume for normal basement spaces.

m3 (22)

FORCED CONTINUOUS VENTILATION

m3/h (23)

FORCED VENTILATION HEAT EXCHANGER EFFICIENCY

% (24)

Assume 70% if actual efficiency not available.

INFILTRATION LOSS COEFFICIENT

$$\left((21) \times (22) \div (23) \times \frac{100 - (24)}{100} \right) \times 0.3345 = (25) \text{ W/C}$$

4. Internally generated odours and other contaminants require certain minimum ventilation rates. If natural infiltration and forced ventilation are not adequate, then the occupants will resort to artificial added ventilation by opening of windows, operation of toilet and kitchen fans, etc. Therefore a minimum estimated air change of .3 should be assumed, unless continuous forced ventilation is provided. When using air tight construction be careful to provide adequate combustion air for the furnace and the fireplace. Additional mechanical ventilation may be required for the comfort and health of the occupants.

G BASEMENT WALL ABOVE GRADE LOSSES

WALL TYPE	A	B	C	D
Description				

BASEMENT WALL ABOVE GRADE AREA (m2)

Gross area minus glass in basement wall above grade.

26A	26B	26C	26D

BASEMENT WALL ABOVE GRADE RESISTANCE (Cm2/W) See Note No. 5

	A	B	C	D
Exterior Film	.10	.10	.10	.10
Exterior Materials				
Insulation				
Air Space (.17)				
Interior Finish (.08)				
Interior Film	.12	.12	.12	.12
SUM=	27A	27B	27C	27D

LOSS COEFFICIENTS (W/C)

Line 26/Line 27 E.g. 26A/27A=28A

28A	28B	28C	28D

TOTAL WALL ABOVE GRADE LOSS COEFF. 28A+28B+28C+28D= 29 W/C

---

5. If insulation (+ air space if any) is in stud space, reduce insulation (+ air space) resistance to

$$\frac{1}{.19 + .85/R_{\text{Insulation and air space}}}$$

The above is correct for the standard stud wall. For a wall with R 2.11 insulation and 400 mm stud spacing, insulation is reduced to R 1.69 (reduction of 20%).

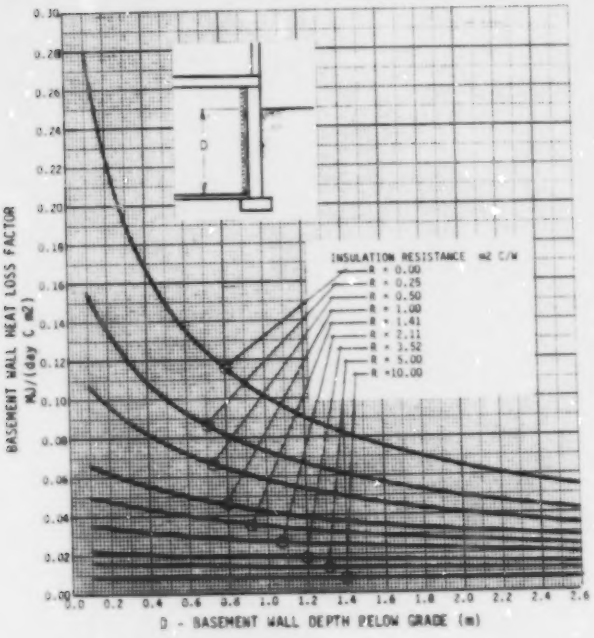
For other stud walls use

$$\frac{1}{F/(\text{stud depth mm} \times 0.0087) + (1-F)/R_{\text{Insulation}}}$$

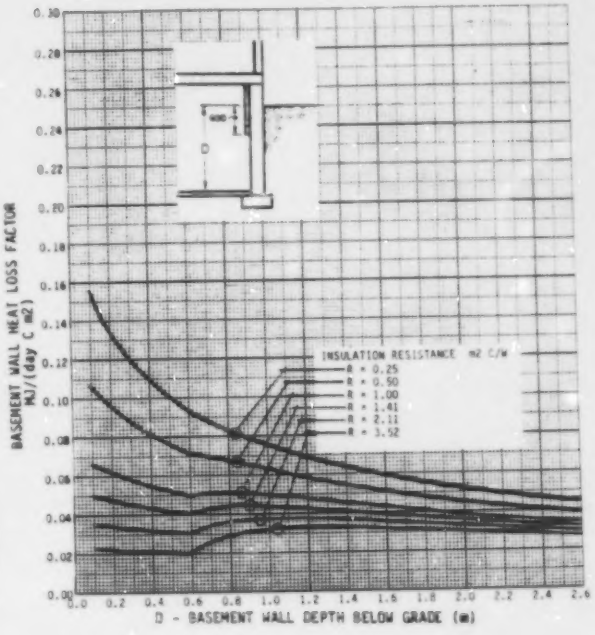
Where F = fraction of wall area taken up by wood framing or joists.

H BASEMENT WALL BELOW GRADE LOSSES

GRAPH No. 1
Use this graph for basement wall losses for cases with full height basement wall insulation and with no basement wall insulation.



GRAPH No. 2
Use this graph for basement wall losses for cases with basement wall insulation extending to 600 mm below grade.


BASEMENT WALL HEAT LOSS FACTOR MJ/(day C m2)
INSULATION RESISTANCE m2 C/W
R = 0.25
R = 0.50
R = 1.00
R = 1.41
R = 2.11
R = 3.52
D - BASEMENT WALL DEPTH BELOW GRADE (m)

If insulation with a reduced R value is used for the lower portion of the wall or insulation depth is not as shown on the above graphs, use values interpolated between the two graphs.

See Note No. 6

BASEMENT WALL DEPTH BELOW GRADE — Average depth ____ m (30)

BASEMENT WALL INSULATION RESISTANCE — R-VALUE of insulation only (Zero (0) if no insulation). ____ Cm2/W (31)

BASEMENT WALL HEAT LOSS FACTOR
Insulation depth below grade ____ m
Graph No. ____ ____ MJ/dayCm2 (32)

BASEMENT WALL BELOW GRADE AREA ____ m2 (33)

BASEMENT WALL MONTHLY LOSS FACTOR
____ (32) x ____ (33) x 30.3 = ____ MJ/month C (34)

6. Detached houses have additional basement losses due to corner effects. On the other hand, the sidewalls of the basement of a detached house are generally sheltered to some degree by the neighbouring houses. These two effects largely cancel each other and therefore can be neglected for a house in an average urban setting.

For a house on a corner lot (one side not sheltered) the corner effect can be accounted for by changing 3.6 to 3.2 in the denominator in line 38. For a house exposed on all sides change 3.6 to 2.8.

BASEMENT FLOOR LOSSES

BASEMENT FLOOR AREA

Include vertical area at change in floor level. ____ m2 (35)

BASEMENT FLOOR INSULATION RESISTANCE

R-VALUE of insulation only (Zero (0) if no insulation). ____ Cm2/W (36)

MEAN ANNUAL TEMPERATURE DIFFERENCE

BASEMENT SPACE TEMPERATURE ____ C MINUS

ANNUAL MEAN OUTSIDE AIR TEMPERATURE ____ C = ____ C (37)

Obtain from Weather Data Tables

Weather Data Location used _____

MONTHLY BASEMENT FLOOR LOSS See Note No. 7

$$\frac{(35) \times (37) \times 2.62}{(36) + 3.6} = \text{MJ/month (38)}$$

---

7. Detached houses have additional basement losses due to corner effects. On the other hand, the sidewalls of the basement of a detached house are generally sheltered to some degree by the neighbouring houses. These two effects largely cancel each other and therefore can be neglected for a house in an average urban setting.

   For a house on a corner lot (one side not sheltered) the corner effect can be accounted for by changing 3.6 to 3.2 in the denominator in line 38. For a house exposed on all sides change 3.6 to 2.8.

J ADJUSTMENT FOR ATTACHED UNHEATED SPACES

NOTE: This adjustment can be made for garages, porches, sunrooms and similiar unheated attachments. For an average garage attached to a well insulated wall this adjustment may be neglected. It is important for sunrooms and porches.

CONDUCTANCE HOUSE TO ATTACHED SPACE Include wall, doors windows between HOUSE INTERIOR and the ATTACHED UNHEATED SPACE

Wall A	/	Wall R	=	
Door A	/	Door R	=	
Window A	/	Window R	=	
Area	/	Resistance	=	

Total Conductance (House to attached space) = W/C (39)

CONDUCTANCE ATTACHED SPACE TO OUTDOORS Include all elements between UNHEATED SPACE and OUTDOORS

Wall A	/	Wall R	=	
Door A	/	Door R	=	
Window A	/	Window R	=	
Ceiling A	/	Ceiling R	=	
Area	/	Resistance	=	
Volume	X 0.3345		=	

Total Conductance (Unheated space) = W/C (40)

NOTE: For a garage, line 40 is in the range of 50 to 250 W/C

See Note No. 8.

ADJUSTMENT FOR ATTACHED UNHEATED SPACES

$$\frac{(39)}{1 + (40)/(39)} = (41) \text{ W/C}$$

8. Floor (slab on grade) loss for an unheated space can be neglected.

K *** TOTAL ABOVE GRADE LOSS COEFFICIENT ***

Sum all the previously calculated loss coefficients.

The total above grade loss coefficient excludes below grade basement losses and must not be used to size equipment.

Note that the adjustment for unheated spaces must be treated as a negative number.

Window Loss		4
Wall loss		8
Ceiling Loss		12
Door Loss		16
Special Portions Loss		20
Infiltration Loss		25
Basement Wall Above Grade Loss		29
SUBTRACT: Adjustment For Unheated Spaces	-	41
TOTAL Above Grade Loss Coefficient =		42 W/C

L

*** GROSS MONTHLY HEAT LOSS CALCULATION ***

LOCATION _____ WEATHER DATA LOCATION _____

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
DEGREE DAY FACTORS Obtain From Weather Data Tables										(50)
MONTHLY ABOVE GRADE LOSS MJ/Month (50) x (42)										(51)
MEAN ANNUAL TEMPERATURE DIFFERENCE Enter (37) in each column										(52)
CORRECTION FOR MONTHLY FLUCTUATION See Note No. 9	-10.4	-6.0	0.0	+6.0	+10.4	+12.0	+10.4	+6.0	0.0	(53)
MONTHLY TEMPERATURE DIFFERENCE (52) + (53)										(54)
MONTHLY BASEMENT WALL LOSS (54) x (34)										(55)
MONTHLY BASEMENT FLOOR LOSS Enter (38) in each column										(56)
GROSS MONTHLY HEAT LOSS MJ/Month Sum of (51) + (55) + (56)										(60)

9. Monthly fluctuations given in the calculation forms correspond to 12°C amplitude at 5 cm below grade. This is approximately correct for all Ontario locations with such measured data. For locations with known amplitudes that differ substantially from 12°C, multiply each number in line 53 by "amplitude"/12.

M *** HEATING ENERGY REQUIREMENT CALCULATION ***

INTERNAL GAINS (MJ/month) Average Occupancy during 24 hours (see Note 10) [Persons] x 200 + 1300 = [ ] 61

ROOM THERMOSTAT SETTING (deg C) Suggested Setting : 20 C [ ] 62

NET INTERNAL GAINS (MJ/month) (Can be negative) [61] - [42] x ([62] - 18) x 2.62 = [ ] 63

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
GROSS MONTHLY HEAT LOSS (MJ/month) Enter Numbers of Line 60										64
MONTHLY NET INTERNAL GAINS Enter Line 63 in each column										65
NET MONTHLY HEAT LOSS (MJ/mo) 64 - 65 Enter zero (0) if negative										66
MONTHLY SOLAR GAINS RATE (SOUTH) MJ/m2/month from weather tables										67
GLAZING TYPE FACTOR 1.1 single glazing (1.0 double glazing) .91 triple glazing .83 quadruple glzg										68
OVERHANG OR OBSTRUCTION SHADING FACTOR Use 1.0 if no shading. See Note 11										69
CLEAR GLASS AREA (SOUTH) Exclude framing Use 75% of south window area in heat loss calcs, or measured clear area										70
MONTHLY SOLAR GAINS 67 x 68 x 69 x 70 MJ/Month See Notes 12 & 13 (Form L-13)										71
SOLAR/LOAD RATIO 71 / 66										72
MONTHLY SOLAR UTILIZATION EFFICIENCY See Note No. 14 (On Form L-13)										73
MONTHLY PASSIVE HEAT 71 x 73 MJ/month										74
MONTHLY AUXILIARY HEAT 66 - 74 MJ/month										75

ANNUAL AUXILIARY HEAT Add all numbers in 75 [ ] MJ/Year

10. Internal gains rate due to lighting, appliances, hot water tank losses, is estimated at 1300 MJ/month for a house with 100-150 m^2 floor area. A house with twice as much floor area may have 50% higher internal gains. Use measured internal gains where available. Measured electricity consumption may be used after deductions for heat exhausted by clothes dryers and kitchen exhaust fans as well as outdoor electricity use.

11. For a discussion of shading by overhangs, protruding house walls, trees and other obstructions see 3.6 Shading Effects. See also 3.7 Effects of Off-True-South Orientation.

12. In a more refined calculation, solar gains through other than south glazing may be considered. In an urban setting, side walls are generally shaded by neighbouring housing. Therefore glass only in the front wall and the rear wall needs to be considered. Solar gains through glazing with other than south orientation is calculated in the same manner as for south glazing. For housing with poorly insulated ceilings or walls, substantial solar gains take place through such walls or ceilings. The sum of solar gains through glass, walls and ceiling for each month is entered on Line 71.

Solar gain through ceiling can be estimated by means of the following formula:

$$S_c = (a-.4) \times S_i \times 0.08/ (R+3)$$

where: S_c - solar gain rate through ceiling in MJ/m^2/month

a - solar absorptivity of roof
.8 for dark surfaces
.6 for medium surfaces
.4 for light surfaces

S_i - incident solar on horizontal surface in MJ/m^2/month

R - overall resistance of ceiling

0.08 - average resistance of air film during hours of substantial sunshine (obtained from extensive hourly computer simulations)

.4 - accounts for the effects of infrared sky radiation

3 - the ventilated attic effect

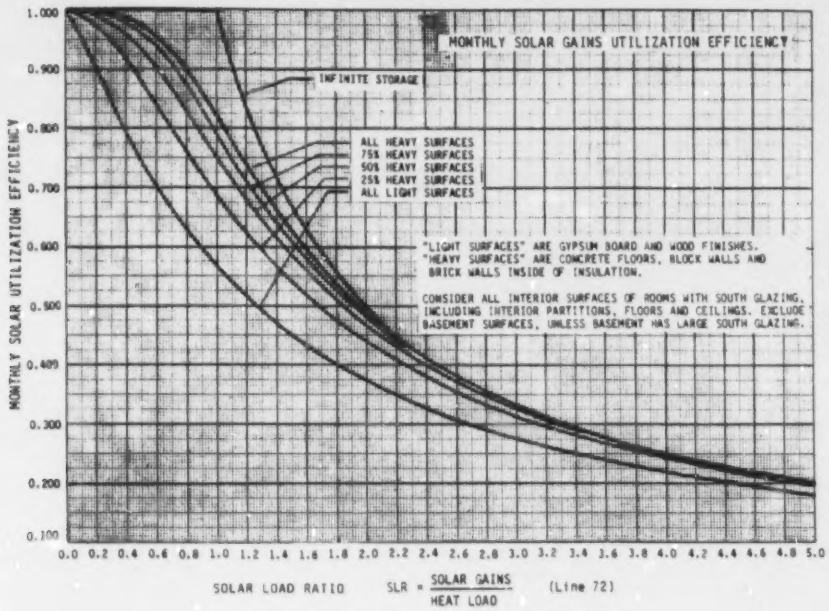
The net useful gain through the opaque south wall is:

$$S_w = S_s \times 0.06 / R$$

Where: S_s - solar gain for double glazed south windows, MJ/m^2/month

R - overall resistance of wall

Use of the window solar gain in place of the incident solar, accounts for the solar absorptivity of a medium coloured wall. Increase solar window gains by 30% for dark walls and decrease by 30% for light walls. The magnitude of the infrared sky radiation loss is such that it approximately balances the useful diffuse solar gains on the north wall and therefore both can be omitted.


MONTHLY SOLAR GAINS UTILIZATION EFFICIENCY
INFINITE STORAGE
ALL HEAVY SURFACES
75% HEAVY SURFACES
50% HEAVY SURFACES
25% HEAVY SURFACES
ALL LIGHT SURFACES
"LIGHT SURFACES" ARE GYPSUM BOARD AND WOOD FINISHES.
"HEAVY SURFACES" ARE CONCRETE FLOORS, BLOCK WALLS AND BRICK WALLS INSIDE OF INSULATION.
CONSIDER ALL INTERIOR SURFACES OF ROOMS WITH SOUTH GLAZING, INCLUDING INTERIOR PARTITIONS, FLOORS AND CEILINGS. EXCLUDE BASEMENT SURFACES, UNLESS BASEMENT HAS LARGE SOUTH GLAZING.
MONTHLY SOLAR UTILIZATION EFFICIENCY
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8 5.0
SOLAR LOAD RATIO SLR = SOLAR GAINS / HEAT LOAD (Line 72)

13. A portion of the solar gains in sun porches, glazed vestibules and attached greenhouses enters the house and constitutes a useful solar gain. In essence the solar energy goes back to the outdoors through the exterior skin of the porch as well as through the house and its skin. The split of the energy flow can be calculated using the principle of superimposition and the appropriate series/parallel resistances.

Approximately the useful house gain is calculated as follows:

$$G_h = G_g \frac{(39) - C}{(39) + (40) - C}$$

where G_h = useful monthly house gain

G_g = monthly solar gain to sunporch, vestibule or greenhouse

C = small correction for the exact calculation (may be neglected)

$$C = \frac{(39) \times (39)}{(42) \times (41)}$$

The above calculation can be used for solar greenhouses communicating with the house through a mass wall without insulation. Mass walls can be thought of as offering little resistance to intermittent solar gain energy flow. Solar gains should be considered to be entering the mass wall directly. Therefore conductances for solar gains to the indoors and to the outdoors should be recalculated accordingly.

14. If the SLR value is beyond the range of the chart (greater than 5) then all of the heating requirement will be satisfied by the solar energy. Enter numbers from line No. 66 into line No. 74.

A more exact way than indicated in Part I, section 1.6.1, to deal with a variety of surfaces is to use the Average Solar Absorption Factor (Line No. 85) determined in the Heat Storage Capacity calculation that may be found elsewhere in the present calculation forms. The graphs in the Monthly Solar Utilization Efficiency figure were derived for the following Average Solar Absorption Factors:

% Heavy Surfaces	Average Solar Absorption Factor
0	0.23
25	0.38
50	0.54
75	0.70
100	0.86

Graphs are for a 5 deg. C. temperature swing during sunny winter days. Higher or lower temperature swings have a minor effect. As an illustration of this effect the following efficiencies are determined for SLR = 0.5:

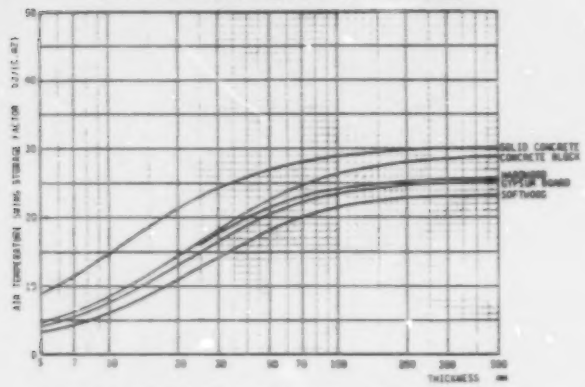
% Heavy Surfaces	3 deg. Swing	5 deg. Swing	7 deg. Swing
0	.71	.75	.77
25	.85	.88	.89
50	.92	.93	.94
75	.95	.96	.97
100	.97	.98	.98

*** HEAT STORAGE CAPACITY CALCULATION ***

PROJECT NAME _____
LOCATION _____

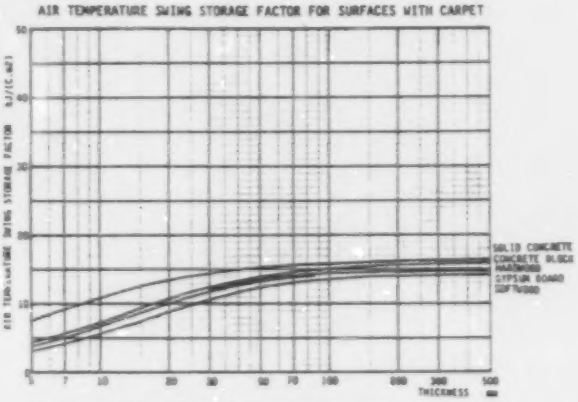
A HEAT STORAGE GRAPHS

AIR TEMPERATURE SWING STORAGE FACTOR FOR BARE SURFACES



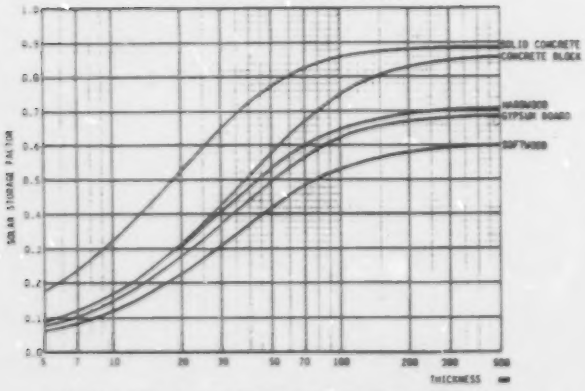
Note: For 13mm gypsum board and wood studs use 11.3 Swing Storage Factor.For hardwood floors with wood joists use 14.0 Swing Storage Factor.

AIR TEMPERATURE SWING STORAGE FACTOR FOR SURFACES WITH CARPET



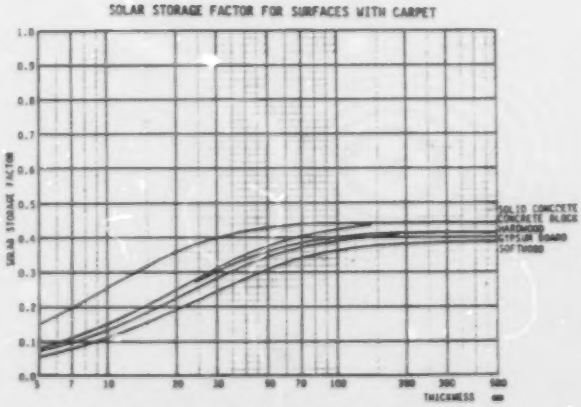
Note: For 13mm chipwood subfloor and wood joists use 9.3 Swing Storage Factor

SOLAR STORAGE FACTOR FOR BARE SURFACES



Note: For 13mm gypsum board and wood studs use .24 Solar Storage Factor.For hardwood floors with wood joists use .31 Solar Storage Factor.

SOLAR STORAGE FACTOR FOR SURFACES WITH CARPET



Note: For 13mm chipwood subfloor and wood joists use .22 Solar Storage Factor.

HEAT STORAGE CAPACITY CALCULATION

For Room(s) with South Glazing

B SOLAR STORAGE

	Floor	----- Walls and Ceiling ------			Sum for all SURFACES
Area m2 (See Note 1)	(80A) +	(80B) +	(80C) +	(80D) =	(80)
Material					
Closest Graph Material					
Thickness mm					
Carpet (yes/no)					
Solar Storage Factor See Note No. 2	(81A)	(81B)	(81C)	(81D)	(81)
Multiply Factors by Appropiate Areas Line 80 x Line 81 E.g. (80A) x (81A) = (82A)	(82A) +	(82B) +	(82C) +	(82D) =	(82)
Swing Storage Factor See Note No. 3	(83A)	(83B)	(83C)	(83D)	(83)
Multiply Factors by Appropiate Areas Line 80 x Line 83 E.g. (80A) x (83A) = (84A)	(84A) +	(84B) +	(84C) +	(84D) =	(84)

Average Solar Absorption Factor See Note No. 4

$$\frac{Y \times (81A) + (82) / (80)}{2} = (85)$$

Y=1.0 if no carpet
Y=0.8 if there is a carpet

Clear South Glass Area m2 (86)

Sunny winter day solar gains to time of swing maximum: Z x (86) = kJ (87)

Z = 15 400 kJ/m2 for single glazing
Z = 14 000 kJ/m2 for double glazing
Z = 12 700 kJ/m2 for triple glazing
Z = 11 600 kJ/m2 for quadruple glazing

TOTAL SOLAR STORAGE (Without Temperature Swing): (85) x (87) = kJ (88)

---

1. There are four columns provided in the calculation forms for surfaces of different materials. Floor has to be treated separately. Walls, partitions and ceilings of the same material can be lumped together. In the case of an interior brick or block partition between two rooms, include the full thickness of such masonry if it communicates with a room without significant south glazing. Include half thickness of such masonry if it is shared with another room with south glazing.

   Assume that doors are open in a residence during the day. Doorways and archways to a room with significant south glazing should be omitted from the calculation. Such openings to rooms without significant south glazing are good absorbers of heat and are to be included in the area of such partition. For higher accuracy lump such areas with the surfaces of "heavy" material.

2. Read Solar Storage Factor from graph (Form HS1) for the appropriate material. Note separate graphs for surfaces covered with carpets. For Aspenite chipboard and Platewood particleboard use "hardwood" graphs, "softwood" for plywood. Use solid concrete graph for brick.

3. Read Swing Storage Factor from graph (Form HS1) for the appropriate material. Note separate graphs for surfaces covered with carpets.

4. Floor Storage Factor (Box 81A) is treated differently from the other storage factors at it represents the target area for the solar image of the window during most of a sunny winter day.

C AIR SWING STORAGE

Design Temperature Swing
Use 3 to 7 deg C (5 deg is suggested) — C (89)

Floor to Basement Storage
Include only if basement has no significant south glazing. If there is a carpet deduct 30%.
m2 x (89) x16 = kJ (90)

Partitions to Adjacent Rooms Storage
Include only those to rooms that do not have significant south glazing.
m2 x (89) x16 = kJ (91)

Ceiling to Upper Floor Storage
Applies only to lower floor south spaces that communicate with upper floor spaces without south glazing. If there is a carpet on the upper floor deduct 30%.
m2 x (89) x16 = kJ (92)

Open Doors and Stairwells to spaces without significant south glazing. See Note No. 5
m2 x (89) x200 = kJ (93)

Furniture Allowance
See Note No. 6
floor area m2 x (89) x12 = kJ (94)

Furnace Circulation Allowance. (NIL for electrical baseboard heating systems) See Note No. 7
floor area m2 x (89) x15 = kJ (95)

Storage in Floor, Wall and Ceiling Materials
(84) x (89) = kJ (96)

TOTAL Air Temperature Swing Storage
Sum of Lines (90), (91), (92), (93), (94), (95), (96) = kJ (97)

TOTAL SOLAR AND AIR SWING STORAGE
(88) + (97) = KJ (98)

5. Area of door or stairwell used in this calculation should not exceed 10% of the area of the connecting wall for doors or connecting floor/ceiling for stairwells. If the actual area is greater than 10% then use 10%. Assume that all doors are open in a residence during the day.

6. The furniture allowance includes for a typical weight of furniture per square metre of floor area, represented by storage of 12 KJ/C/m^2.

7. Storage factor of 15 is based on a furnace circulation rate of 20m^3/h sq. m. of floor area. Adjust factor proportionately if extra high air circulation is used. If return grilles are placed near ceiling, then increase the furnace circulation allowance by 50%. If a separate basement destratification fan with separate ductwork from a massive basement to grilles near ceiling of the southern rooms is installed, then add the following extra storage:

Room Air Floor Rate (m^3/h) x Design Temperature Swing x 1.2 (kJ)

Factor of 1.2 in the above formula is approximate for average coupling of air to the basement mass. For very good coupling, such as in properly designed rock beds, this factor can be as high as 3.0.

D REQUIRED STORAGE

Internal Gains
See Note No. 8 — kJ (99)

TOTAL GAINS — (87) + (99) = kJ (100)

Volume of South Space Being Considered — m3 (101)

Losses to Outdoors
See Note No. 9

Windows	Area m2	/ R Cm2/W	= W/C (102)
Doors	Area m2	/ R Cm2/W	= W/C (103)
Net Wall A	Area m2	/ R Cm2/W	= W/C (104)
Net Wall B	Area m2	/ R Cm2/W	= W/C (105)
Net Wall C	Area m2	/ R Cm2/W	= W/C (106)
Ceiling	Area m2	/ R Cm2/W	= W/C (107)

Infiltration — $\dfrac{0.5 \times (25) \times (101)}{(22)}$ = W/C (108)

Sum of Heat Loss Factors
Add Lines (102) (103) (104) (105) (106) (107) and (108) — W/C (109)

TOTAL LOSSES — (109) x (90 + 8.06 x DDF) = kJ (110)

DDF - Degree Day Factor for January
See Note No. 10

REQUIRED STORAGE — (100) - (110) = kJ (111)

If Required Storage (111) is less than Total Solar and Air Swing Storage (98), then adequate storage is available.

If not, then the actual temperature swing will be greater than the Design Temperature Swing 89 , indicating that additional storage is required.

NOTE: Rather than comparing the Stored Heat vs Required Storage, the Estimated Temperature Swing can be calculated as follows:

Temperature Swing = (89) x $\left(\dfrac{(111) - (88)}{(97)}\right)$ = C

8. Enter internal gains estimated for the period of 8 a.m. to 2 p.m. for the specific space or spaces being considered. The following values are suggested.

Living room	-	1500 kJ
Family room	-	1500 kJ
Dining room	-	1500 kJ
Kitchen	-	3000 kJ
Bedroom	-	NIL

9. Consider only the losses from the south facing space or spaces being considered in the storage calculation, not the whole house. Use component resistance values from the Heat Loss Calculation. For windows with shutters assume the shutters are open.

10. The factors of 90 and 8.06 convert degree day factor to a temperature difference, increase space temperature above the degree day base of 18C and convert Wh to kJ.

Degree day factor (DDF) for January can be found in the Weather Data Tables for a specific location.

APPENDICES

A. Weather Data

B. R-Values for Various Construction Materials

C. Example of Completed Short Form Calculations

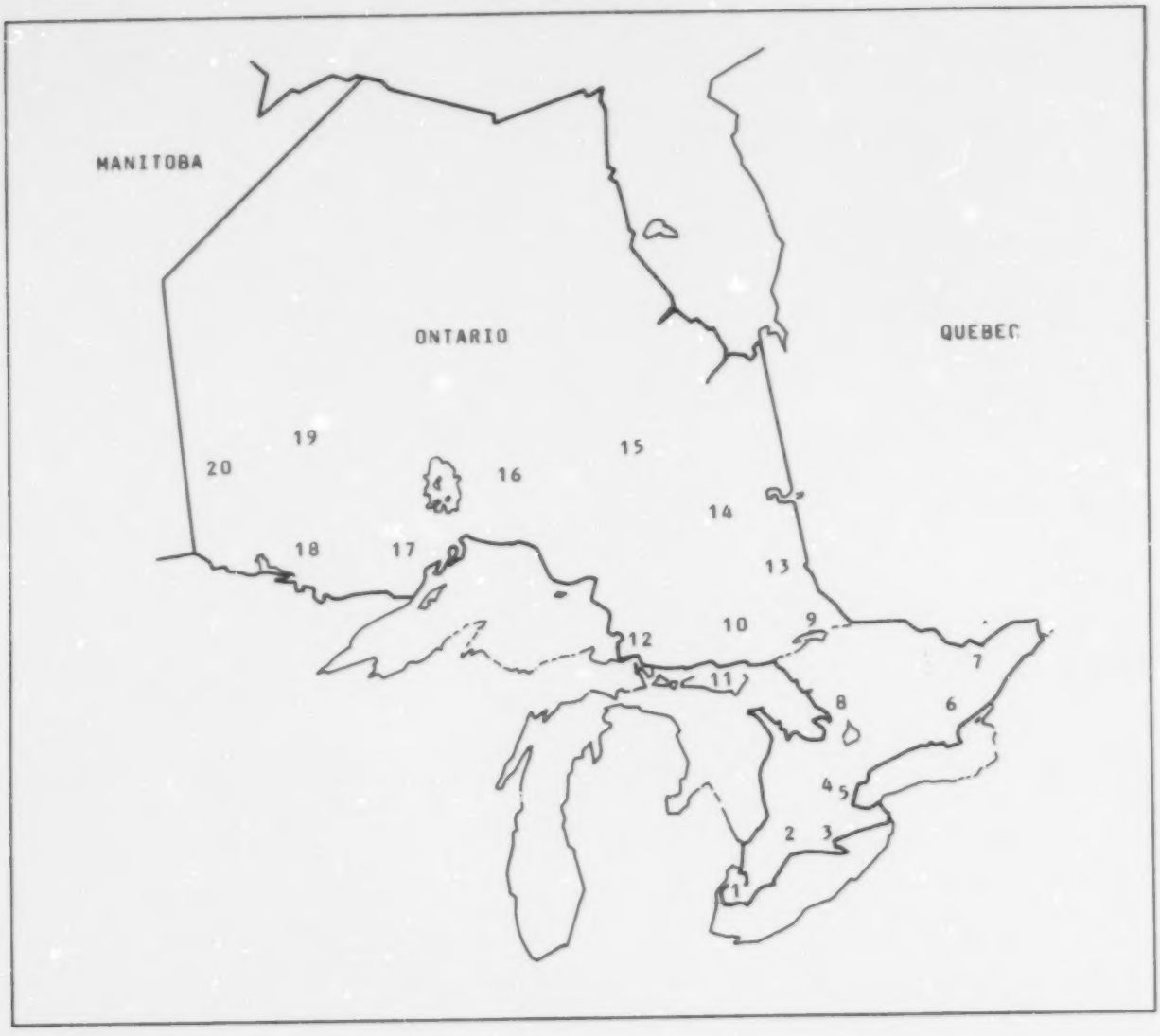
D. Example of Completed Long Form Calculations

E. Example of Completed Heat Storage Calculations

F. Further Reading

APPENDIX A: WEATHER DATA

WEATHER DATA LOCATIONS



Atikokan	18	Ottawa	7
Earlton	13	Sault Ste. Marie	12
Geraldton	16	Simcoe	3
Gore Bay	11	Sioux Lookout	19
Kapuskasing	15	Sudbury	10
Kenora	20	Thunder Bay	17
Kingston	6	Timmins	14
London	2	Toronto (City)	5
Muskoka	8	Toronto (Metro)	4
North Bay	9	Windsor	1

ATIKOKAN (ONT) Latitude 48.75 Annual Mean Temp 1.1

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	20.66	34.72	58.53	85.28	97.63	81.64	69.22	41.27	24.01

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	191	180	149	192	246	290	284	217	169
S/E	191	149	111	135	175	227	265	243	221
S/W	194	150	112	136	177	227	262	241	211
East	149	93	58	59	78	126	192	214	238
West	152	94	59	60	79	126	189	210	225
North	58	43	34	32	40	59	86	84	105
Horizontal (Incident)	369	227	132	120	161	256	409	518	610

EARLTON A (ONT) Latitude 47.70 Annual Mean Temp 2.0

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	18.48	33.82	52.97	82.23	92.05	78.40	68.61	41.67	22.37

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	171	156	126	195	227	279	284	211	165
S/E	170	128	94	138	166	227	267	239	211
S/W	177	138	100	141	166	220	263	233	204
East	137	85	54	62	80	133	198	216	229
West	145	93	57	64	80	128	195	209	220
North	63	47	35	37	45	67	98	97	114
Horizontal (Incident)	353	222	129	133	169	266	418	515	591

GERALDTON (ONT) Latitude 49.70 Annual Mean Temp -0.4

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	22.84	37.91	60.95	89.57	101.71	87.58	77.66	47.86	27.88

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	159	150	123	181	223	271	292	221	164
S/E	159	124	91	126	160	212	271	245	202
S/W	158	126	94	128	159	213	264	241	203
East	125	79	49	54	72	119	195	215	213
West	125	80	51	54	72	120	189	211	215
North	54	40	30	30	38	58	91	90	104
Horizontal (Incident)	310	194	111	109	145	237	402	506	563

GORE BAY A (ONT) Latitude 45.88 Annual Mean Temp 5.1

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	11.75	25.92	41.77	63.28	75.15	67.54	59.79	37.12	20.97

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	202	198	127	152	204	258	284	211	166
S/E	205	164	95	109	149	209	268	246	216
S/W	210	171	101	113	153	208	265	242	222
East	163	105	53	54	74	125	197	222	237
West	168	111	58	56	77	124	195	218	246
North	64	47	33	34	43	62	90	86	108
Horizontal (Incident)	420	269	137	124	165	260	436	555	653

KAPUSKASING A (ONT) Latitude 49.42 Annual Mean Temp 0.5

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	21.19	36.34	57.95	87.54	98.02	83.46	73.34	45.31	26.35

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	163	151	119	182	218	272	290	216	174
S/E	164	126	91	130	160	221	273	236	215
S/W	163	129	90	129	155	209	261	237	211
East	132	84	52	58	75	128	200	210	230
West	132	86	51	57	72	120	189	211	223
North	63	48	34	33	41	63	98	100	120
Horizontal (Incident)	330	211	118	117	150	249	410	500	588

KENORA A (ONT) Latitude 49.80 Annual Mean Temp 2.1

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	17.14	33.10	58.41	85.88	97.86	79.16	67.22	39.87	20.81

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	204	182	143	203	250	301	308	231	187
S/E	200	151	105	143	178	238	285	255	240
S/W	204	151	110	142	179	233	279	255	231
East	154	95	55	60	79	132	204	222	257
West	158	95	58	60	79	128	198	221	246
North	61	45	34	32	41	60	91	90	115
Horizontal (Incident)	380	228	127	120	157	256	422	534	647

000033

KINGSTON A (ONT) Latitude 44.22 Annual Mean Temp 6.7

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	8.67	23.19	37.90	59.86	69.07	61.43	52.49	32.28	17.82

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	202	222	146	178	231	264	247	193	158
S/E	215	191	116	129	172	213	240	229	209
S/W	211	186	110	131	172	216	236	226	207
East	175	123	66	65	88	129	185	211	235
West	172	119	61	65	88	131	181	208	232
North	66	50	36	39	50	66	88	85	114
Horizontal (Incident)	441	303	158	149	196	283	421	539	631

LONDON A (ONT) Latitude 43.03 Annual Mean Temp 7.3

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	8.74	23.10	38.71	57.53	65.94	58.88	50.62	30.21	15.83

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	186	207	135	136	183	221	218	179	145
S/E	197	177	104	103	140	185	213	219	199
S/W	202	178	106	102	140	182	210	210	193
East	164	116	60	56	78	118	167	208	226
West	170	117	62	56	78	116	164	198	219
North	68	50	35	37	48	65	84	86	107
Horizontal (Incident)	427	301	155	134	179	262	392	523	607

MUSKOKA A (ONT) Latitude 44.97 Annual Mean Temp 4.8

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	13.52	28.06	44.04	67.18	76.14	67.34	58.43	35.16	19.52

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	188	195	118	165	199	242	260	208	158
S/E	197	166	93	122	149	199	250	242	210
S/W	198	168	93	121	150	197	246	240	204
East	162	110	56	63	79	123	190	221	234
West	164	111	56	62	80	121	185	219	226
North	67	51	36	39	47	66	91	92	114
Horizontal (Incident)	411	278	139	141	175	262	425	561	618

NORTH BAY A (ONT) Latitude 46.37 Annual Mean Temp 3.6

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	15.80	31.16	49.11	74.18	82.96	71.51	62.34	38.50	20.37

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	178	175	116	171	213	251	270	213	168
S/E	182	147	92	126	158	201	256	242	216
S/W	182	152	92	124	158	200	252	240	210
East	148	97	56	64	81	129	194	219	235
West	148	102	56	63	81	123	191	218	228
North	66	51	37	40	48	69	101	100	119
Horizontal (Incident)	377	251	133	137	174	262	423	542	620

OTTAWA NRC (ONT) Latitude 45.45 Annual Mean Temp 6.0

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	10.59	25.50	42.32	67.39	75.90	66.49	55.75	31.65	14.77

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	180	200	137	182	229	249	251	189	147
S/E	187	169	106	130	169	199	239	221	196
S/W	184	166	102	131	166	203	237	218	189
East	150	105	58	61	81	119	178	201	218
West	147	103	55	61	80	121	177	197	208
North	58	41	30	34	42	60	85	78	102
Horizontal (Incident)	378	257	134	132	173	253	403	510	576

SAULT STE. MARIE A (ONT) Latitude 46.48 Annual Mean Temp 4.2

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	14.26	27.93	44.84	66.23	75.45	68.96	61.84	38.68	24.09

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	186	173	123	144	165	238	276	206	169
S/E	188	145	94	105	125	192	260	236	218
S/W	193	147	95	106	124	193	257	236	222
East	150	94	52	52	66	116	192	213	236
West	155	96	54	52	66	117	190	214	242
North	64	47	32	33	42	63	93	89	110
Horizontal (Incident)	389	243	131	117	147	247	425	533	646

000085

SIMCOE A (ONT) Latitude 42.85 Annual Mean Temp 7.9

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	7.72	21.94	37.30	53.90	63.13	56.00	49.03	29.13	15.18

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	186	207	137	140	192	219	212	179	149
S/E	200	178	108	107	147	187	211	219	199
S/W	200	179	106	105	146	180	205	207	194
East	169	118	64	60	82	122	167	208	226
West	170	119	63	58	82	118	162	195	218
North	72	53	37	39	51	68	85	89	112
Horizontal (Incident)	429	307	161	141	189	267	392	524	604

SIOUX LOOKOUT A (ONT) Latitude 50.12 Annual Mean Temp 1.0

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	19.36	35.44	60.28	88.76	100.15	82.28	70.40	43.10	23.97

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	183	162	139	198	246	299	304	231	177
S/E	179	134	104	138	174	233	279	255	225
S/W	183	135	103	138	176	231	276	255	218
East	139	85	55	57	75	127	198	222	238
West	143	85	55	57	77	125	195	222	231
North	59	43	33	30	39	57	89	87	107
Horizontal (Incident)	347	206	121	113	151	249	413	527	609

SUDBURY A (ONT) Latitude 46.62 Annual Mean Temp 3.3

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	15.65	31.26	49.80	75.53	84.87	74.58	64.39	39.59	20.57

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	177	174	133	186	226	272	287	211	161
S/E	182	141	100	132	166	221	274	243	210
S/W	182	153	105	136	165	215	265	237	204
East	147	91	57	62	82	131	204	220	230
West	148	100	60	65	81	127	196	213	223
North	62	47	35	37	46	66	97	94	110
Horizontal (Incident)	371	241	137	135	174	266	433	536	604

THUNDER BAY A (ONT) Latitude 48.37 Annual Mean Temp 2.3

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	18.14	32.94	53.37	77.86	89.42	75.73	65.02	40.17	24.68

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	197	186	172	197	252	303	297	224	173
S/E	200	155	127	137	180	236	275	250	226
S/W	197	154	128	140	182	240	275	252	219
East	157	97	64	59	81	131	199	220	244
West	155	96	65	60	82	134	199	220	234
North	58	43	34	32	42	61	89	83	107
Horizontal (Incident)	381	236	145	123	168	267	427	539	633

TIMMINS A (ONT) Latitude 48.57 Annual Mean Temp 1.1

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	20.36	35.38	56.36	85.61	94.56	82.01	70.65	44.06	24.60

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	170	163	126	186	220	273	285	214	169
S/E	172	135	96	134	162	223	268	237	213
S/W	170	139	97	132	158	210	260	235	208
East	138	89	54	60	78	129	197	211	228
West	138	92	54	59	75	120	191	209	222
North	63	48	34	34	43	62	96	97	116
Horizontal (Incident)	346	223	124	124	159	252	413	508	590

TORONTO CITY (ONT) Latitude 43.67 Annual Mean Temp 8.9

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	5.75	19.02	33.91	52.49	60.55	53.35	46.28	27.15	12.99

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	185	194	122	141	189	203	206	179	141
S/E	195	163	97	102	139	165	200	218	190
S/W	198	166	93	103	141	165	198	207	188
East	159	104	56	50	70	100	152	204	214
West	163	106	53	50	71	100	151	192	211
North	60	43	29	28	38	49	69	80	102
Horizontal (Incident)	412	272	134	117	159	220	358	512	581

TORONTO MET RES STN (ONT) Latitude 43.80 Annual Mean Temp 7.4

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	8.48	23.03	37.89	57.78	66.17	59.04	50.99	30.45	15.63

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	189	191	121	146	200	236	234	190	153
S/E	199	164	97	110	152	196	226	226	196
S/W	193	162	93	109	152	192	223	213	192
East	163	107	58	58	83	122	173	209	213
West	157	105	55	57	83	119	170	195	208
North	71	52	34	37	51	66	86	91	112
Horizontal (Incident)	424	284	143	138	189	269	405	536	597

WINDSOR A (ONT) Latitude 42.27 Annual Mean Temp 9.1

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
DD Factor	5.27	18.84	35.39	53.21	61.28	53.22	44.98	25.84	11.73

Solar Gains for Vertical Double Glazing (MJ/m2/month)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
South	196	225	166	149	196	226	209	179	147
S/E	213	195	130	112	149	189	208	217	206
S/W	208	192	126	111	150	186	202	210	195
East	176	127	73	60	83	120	162	206	235
West	172	125	70	59	83	118	157	197	219
North	67	51	36	37	49	62	77	86	108
Horizontal (Incident)	452	325	179	145	191	272	391	534	632

Thermal Resistance Values (R Values) For Various Construction Materials

Except where noted, the following values are taken from the Canada Mortgage and Housing Corporation publication "Energy Conservation in New Small Residential Buildings".

In this regard, materials can be separated into two principal categories as follows:

— Materials which are assessed on a generic basis such as wood, concrete or bricks. The values given for this category are the only values officially recognized by CMHC.

— Materials which are assessed on a product-by-product basis. Most insulation materials fall into this category. The values given for this category are indicated in **bold face** and are average values provided for guidance only. The values recognized by CMHC for specific products are given in CMHC's Acceptable Building Materials Systems and Equipment Manual (ABM) which is available for examination at CMHC offices.

All values are given in $m^2 \cdot °C/W$.

	Thermal Resistance	
Description	**Per mm**	**For Thickness Listed**
Air Surface Films		
Still Air-Horizontal Surface — Heat Flow Up — e.g. inside of ceilings		0.105
Still Air Horizontal Surface — Heat Flow Down — e.g. inside of floors		0.162
Still Air-Vertical Surface — Heat Flow Horizontal — e.g. inside of walls		0.120
Exterior Air Film (for energy calculations)		0.100
Moving Air — Any Position — e.g. outside of any surface (for max. load calcns. only)		0.030
Air Spaces — Faced with Non-reflective Materials — 12 mm Minimum Dimension		
Horizontal Space — Heat Flow Up		0.150
Horizontal Space — Heat Flow Down		0.180
Vertical Space — Heat Flow Horizontal		0.171
Air Spaces Less than 12 mm in Minimum Dimension		0

Description	Thermal Resistance Per mm	For Thickness Listed
Air Spaces — Faced with Reflective Materials* — 12 mm Minimum Dimension		
Horizontal Space-Faced 1 Side — Heat Flow Up		0.324
Horizontal Space-Faced 2 Sides — Heat Flow Up		0.332
Horizontal Space-Faced 1 Side — Heat Flow Down		0.980
Horizontal Space-Faced 2 Sides — Heat Flow Down		1.034
Vertical Space-Faced 1 Side — Heat Flow Horizontal		0.465
Vertical Space-Faced 2 Sides — Heat Flow Horizontal		0.480
Air Spaces Less than 12 mm in Minimum Dimension		0
Insulation		
Mineral Wool and Glass Fibre	**0.0208**	
Cellulose Fibre	0.0253	
Vermiculite	**0.0144**	
Wood Fibre	**0.0231**	
Wood Shavings	**0.0169**	
Sprayed Asbestos	0.0201	
Expanded Polystyrene Complying with CGSB 51-GP-20M (1978)		
— TYPE 1] Beadboard	0.0257	
— TYPE 2] Beadboard	0.0277	
— TYPE 3] Beadboard	0.0298	
— TYPE 4 Extruded exterior insulation for bsmt. walls	0.0347	
Rigid Glass Fibre Roof Insulation	**0.0277**	
Natural Cork	**0.0257**	
Rigid Urethane or Isocyanurate Board	0.0420	
Mineral Aggregate Board	**0.0182**	
Compressed Straw Board	**0.0139**	
Fibreboard	**0.0194**	
Phenolic Thermal Insulation	0.0304	
Polyisocyanurate (Thermax)	0.0488	
Structural Materials		
Cedar Logs and Lumber	0.0092	
Other Softwood Logs and Lumber	0.0087	
Concrete:		
— 2400 kg/m³	0.00045	
— 1760 kg/m³	0.0013	
— 480 kg/m³	0.0069	
(See also Figure A.1)		
Concrete Block — 3 Oval Core		
Sand and Gravel Aggregate		
— 100 mm		0.125
— 200 mm		0.195
— 300 mm		0.225

* These values may not be used in calculations for areas where the mean annual total degree days exceed 4400 Celsius degree days.

Description	Thermal Resistance Per mm	For Thickness Listed
Structural Materials		
Cinder Aggregate		
— 100 mm		0.125
— 200 mm		0.195
— 300 mm		0.225
Lightweight Aggregate		
— 100 mm		0.264
— 200 mm		0.352
— 300 mm		0.400
Concrete Block — Rectangular Core, Metric Sizes*		
Normal Density (2100 kg/m³)		
— No Insulation in Cores		
— 90 mm		0.17
— 140 mm		0.19
— 190 mm		0.21
— 240 mm		0.24
— 290 mm		0.26
— Cores Filled with Vermiculite		
— 90 mm		—
— 140 mm		0.40
— 190 mm		0.51
— 240 mm		0.61
— 290 mm		0.69
Low Density (1700 kg/m³)		
— No Insulation in Cores		
— 90 mm		0.24
— 140 mm		0.26
— 190 mm		0.30
— 240 mm		0.33
— 290 mm		0.36
— Cores Filled with Vermiculite		
— 90 mm		—
— 140 mm		0.62
— 190 mm		0.81
— 240 mm		0.98
— 290 mm		1.13

* Values for rectangular core concrete block are taken from "Concrete Block Metric Technical Manual", Ontario Concrete Block Association, 1979.

Description	Thermal Resistance	
	Per mm	For Thickness Listed
Sheathing Materials		
Softwood Plywood	0.0087	
Mat-Formed Particle Board	0.0087	
Insulating Fibreboard Sheathing	**0.0165**	
Gypsum Sheathing	0.0062	
Sheathing Paper		0.011
Asphalt Coated Kraft Paper Vapour Barrier		Negligible
Polyethylene Vapour Barrier		Negligible
Cladding Materials		
Fibreboard Siding	0.0107	
Softwood Siding		
Drop — 18 × 184 mm		0.139
Bevel — 12 × 184 mm — Lapped		0.143
Bevel — 19 × 235 mm — Lapped		0.185
Plywood — 9 mm — Lapped		0.103
Brick		
Clay or Shale — 100 mm		0.074
Concrete and Sand/Lime — 100 mm		0.053
Stucco	0.0014	
Metal Siding		
Horizontal Clapboard Profile		0.123
Horizontal Clapboard Profile with Backing		0.246
Vertical V-Groove Profile		0.123
Vertical Board and Batten Profile		Negligible
Roofing Materials		
Asphalt Roll Roofing		0.026
Asphalt Shingles		0.078
Built-Up Roofing		0.058
Wood Shingles		0.165
Crushed Stone — Not Dried	0.0006	
Interior Finish Materials		
Gypsum Board, Gypsum Lath	0.0062	
Gypsum Plaster — Sand Aggregate	0.0014	
Gypsum Plaster — Lightweight Aggregate	0.0044	
Plywood	0.0087	
Hard-Pressed Fibreboard	0.0050	
Insulating Fibreboard	0.0165	
Mat-Formed Particleboard	0.0087	
Carpet Fibrous Underlay		0.366
Carpet Rubber Underlay		0.226
Resilient Floor Coverings		0.014
Terrazzo — 25 mm		0.014
Hardwood Flooring — 9.5 mm		0.060
— 19 mm		0.120
Wood Fibre Tiles — 13 mm		0.209

form S-1

PROJECT NAME _____

LOCATION _____

HEAT LOSS CALCULATIONS - SHORT FORM

For Wall, Ceiling and Basement Wall Above Grade R-values it is satisfactory to use the R-value of the INSULATION ONLY, since the additional resistance of air films and finishing materials is offset by adjustments for wood studs.

Use the more detailed calculation forms where shading effects, solar gains through other than south glazing, or special wall or ceiling construction have to be considered.

All units are metric, including insulation R values

A WINDOW LOSSES

WINDOW AREA (m2) Window dimensions to include frames, ie. use gross wall opening dimensions. Include sliding glass patio doors and basement windows.

21.7 (1)

WINDOW R-VALUE (Cm2/W)
.22 for single glazing
.41 for double glazing
.61 for triple glazing

·61 (2)

WINDOW LOSS (W/C)
Divide Line(1) by Line(2)

35.6 (3)

B CEILING LOSSES

CEILING AREA (m2) 92.3 (7)

CEILING R-VALUE (Cm2/W) 7.0 (8)

CEILING LOSS (W/C) 13.2 (9)
Divide Line(7) by Line(8)

C DOOR LOSSES

DOOR AREA (m2) 3.1 (10)

DOOR R-VALUE (Cm2/W) ·63 (11)
35mm Wood with metal storm .63
45mm Steel with urethane core .44

DOOR LOSS (W/C) 4.9 (12)
Divide Line (10) by Line (11)

D WALL LOSSES

WALL TYPE Description A: E,N,+W B: SOUTH

WALL AREA (m2) Gross wall area minus window area and minus door area. Use inside house dimensions.

153.8 (4A) 29.5 (4B)

WALL R-VALUES (Cm2/W)
(Multiply Imperial R values by .1761 to convert them to metric.)

4.58 (5A) 3.88 (5B)

WALL LOSS W/C 33.6 (6A) 7.6 (6B)
Divide Line (4) by Line (5)
E.g. (4A) / (5A) = (6A)

E BASEMENT WALL ABOVE GRADE LOSSES

AREA (m2) 17.3 (13)
Wall area minus glass in basement wall above grade.

R-VALUE (Cm2/W) 2.64 (14)

LOSS (W/C) 6.6 (15)
Divide Line (13) by Line (14)

F INFILTRATION LOSSES

AIR CHANGE RATE Use measured infiltration AIR CHANGES/HR or the following estimated values:

-Older house (pre 1976)	1.0+ AC/hr
-Conventional construction (fossil fuel)	0.5 AC/hr
-Carefully constructed fossil fuel or average electrically heated house	0.3 AC/hr
-Super energy efficient air tight construction	0.05 - 0.1 AC/hr

Use .3 for the last case if there is no forced ventilation with heat exchanger. 0.3 AC/hr (16)

HEATED VOLUME Include semi-basement rooms that have walk out doors or large windows. Include 1/2 volume for normal basement spaces.

7.9 x 11.2 x (2.7+2.4+2.55/2) = 564 m3 (17)

FORCED CONTINUOUS VENTILATION

— m3/h (18)

FORCED VENTILATION HEAT EXCHANGER EFFICIENCY — % (19)
Assume 70% if actual efficiency not available.

INFILTRATION LOSS

(0.3 (16) x 564 (17) + — (18) x (100 - — (19)) / 100) x 0.3345* = 56.6 (20) W/C

G TOTAL ABOVE GRADE LOSS COEFFICIENT

Sum all the previously calculated losses.

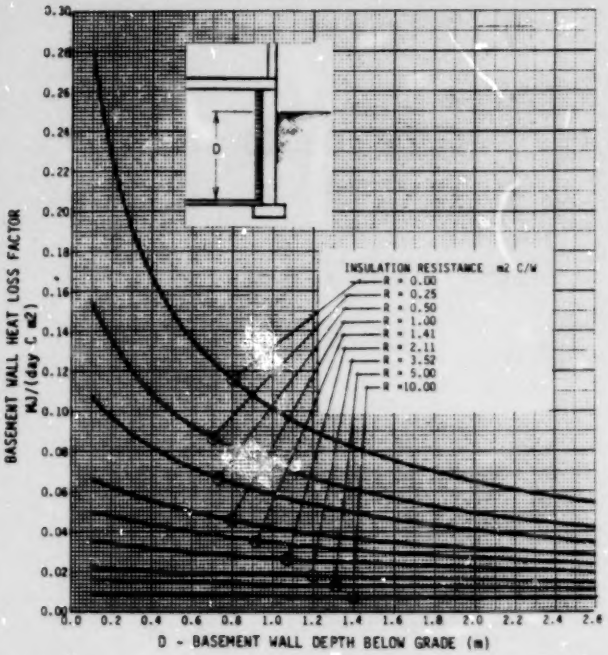
The total above grade loss coefficient excludes below grade basement losses and must not be used to size equipment.

Window Loss	35.6 (3)
Wall Loss (type A)	33.6 (6A)
Wall Loss (type B)	7.6 (6B)
Ceiling Loss	13.2 (9)
Door Loss	4.9 (12)
Basement Wall Above Grade Loss	6.6 (15)
Infiltration Loss	56.6 (20)

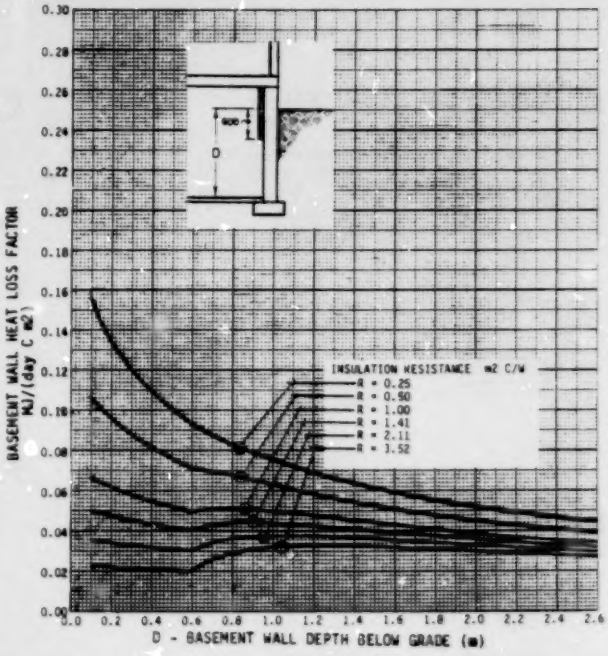
TOTAL Above Grade Loss Coefficient = 158.1 (21) W/C

H BASEMENT WALLS BELOW GRADE

Full height basement wall insulation or no basement wall insulation.



Basement wall insulation to 600 mm below grade.



75.78 - (11.7 + 8.4) = 2

BASEMENT WALL DEPTH BELOW GRADE Average depth — 1.89 m (30)

BASEMENT WALL INSULATION RESISTANCE R-VALUE of insulation only (Zero (0) if no insulation). — 2.64 Cm2/W (31)

BASEMENT WALL HEAT LOSS FACTOR
Insulation depth below grade 1.89 m — 0.02 MJ/dayCm2 (32)

BASEMENT WALL BELOW GRADE AREA
(11.7 + 8.4) × 2 × 2.115 (EXTRA EXPOSED BSMT. IN SOUTH) — 75.78 m2 (33)

BASEMENT WALL MONTHLY LOSS FACTOR
0.02 (32) × 75.78 (33) × 30.3 = 45.92 MJ/month C (34)

I BASEMENT FLOOR LOSSES

BASEMENT FLOOR AREA
Include vertical area at change in floor level. — 98.28 m2 (35)

BASEMENT FLOOR INSULATION R-VALUE
(Zero (0) if no insulation) — 0 Cm2/W (36)

MEAN ANNUAL TEMPERATURE DIFFERENCE

BASEMENT SPACE TEMPERATURE 20 C MINUS
ANNUAL MEAN OUTSIDE AIR TEMPERATURE 7.4 C = 12.6 C (37)
Obtain from Weather Data Tables
Weather Data Location used _____

MONTHLY BASEMENT FLOOR LOSS

98.28 (35) × 12.6 (37) × 2.62 / 0 (36) + 3.6 = 901 MJ/month (38)

J GROSS MONTHLY HEAT LOSS CALCULATION

LOCATION MISSISSAUGA WEATHER DATA LOCATION TORONTO MET RES

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
DEGREE DAY FACTORS Obtain From Weather Data Tables	8.48	23.03	37.89	57.78	66.17	59.04	50.99	30.45	15.63	(50)
MONTHLY ABOVE GRADE LOSS MJ/Month (50) x 158.1 (42)	1341	3641	5990	9135	10461	9334	8062	4814	2471	(51)
MEAN ANNUAL TEMPERATURE DIFFERENCE Enter (37) in each column	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	(52)
CORRECTION FOR MONTHLY FLUCTUATION	-10.4	-6.0	0.0	+6.0	+10.4	+12.0	+10.4	+6.0	0.0	(53)
MONTHLY TEMPERATURE DIFFERENCE (52) + (53)	2.2	6.6	12.6	18.6	23.0	24.6	23.0	18.6	12.6	(54)
MONTHLY BASEMENT WALL LOSS (54) x 45.92 (34)	101	303	579	854	1056	1130	1056	854	579	(55)
MONTHLY BASEMENT FLOOR LOSS Enter (38) in each column	901	901	901	901	901	901	901	901	901	(56)
GROSS MONTHLY HEAT LOSS MJ/Month Sum of (51) + (55) + (56)	2343	4845	7470	10890	12418	11365	10019	6569	3951	(60)

K HEATING ENERGY REQUIREMENT CALCULATION

NET INTERNAL GAINS (MJ/month) (Can be negative) 1800 - 158.1 (42) x 5.24 = 972 (63)

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
GROSS MONTHLY HEAT LOSS (MJ/month) Enter Numbers of Line (60)	2343	4845	7470	10890	12418	11365	10019	6569	3951	(64)
MONTHLY NET INTERNAL GAINS Enter Line (63) in each column	972	972	972	972	972	972	972	972	972	(65)
NET MONTHLY HEAT LOSS (MJ/mo) (64) - (65) Enter zero (0) if negative	1371	3873	6498	9918	11446	10393	9047	5597	2979	(66)
MONTHLY SOLAR GAINS RATE (SOUTH) MJ/m2/month from weather tables	189	191	121	146	200	236	234	190	153	(67)
GLAZING TYPE FACTOR 1.1 single glazing (1.0 double glazing) .91 triple glazing .83 quadruple glzg	.91	.91	.91	.91	.91	.91	.91	.91	.91	(68)
CLEAR GLASS AREA (SOUTH) Exclude framing Use 75% of south window area, or measured clear area.	9.95	9.95	9.95	9.95	9.95	9.95	9.95	9.95	9.95	(70)
MONTHLY SOLAR GAINS (67) x (68) x (70) MJ/Month	1711	1729	1096	1322	1811	2137	2119	1720	1385	(71)
SOLAR/LOAD RATIO (71) / (66)	1.25	.45	.17	.13	.16	.21	.23	.31	.46	(72)
MONTHLY SOLAR UTILIZATION EFFICIENCY Use graph to the right.	.61	.90	.98	.99	.98	.97	.97	.94	.89	(73)
MONTHLY PASSIVE HEAT (71) x (73) MJ/month	1044	1556	1074	1309	1775	2073	2055	1617	1233	(74)
MONTHLY AUXILIARY HEAT (66) - (74) MJ/month	327	2317	5424	8609	9671	8320	6992	3980	1746	(75)

ANNUAL AUXILIARY HEAT Add all numbers in (75): 47386 MJ/Year

PROJECT NAME SUNSET HOUSE
LOCATION MISSISSAUGA

*** HEAT LOSS CALCULATIONS ***

These calculations are designed specifically for the determination of the average heating energy consumption and must NOT be used to size furnaces or other heating equipment. Window losses, infiltration losses and basement losses are lower than the recommended values for the calculation of the maximum instantaneous load for equipment sizing.

All units are metric, including insulation R values.

A WINDOW LOSSES

WINDOW TYPE	A	B	C	D
Description	NORTH	EAST	SOUTH	WEST

WINDOW AREA (m2) Window dimensions to include frames, ie. use gross wall opening dimensions. Include sliding glass patio doors, basement windows and windows from house to unheated attached spaces, but NOT windows from such unheated attached spaces to outdoors.

2.63 (1A)	4.62 (1B)	13.71 (1C)	.74 (1D)

WINDOW RESISTANCE (Cm2/W)
See Note 1 for air spaces which are smaller than 12mm, for night shutters, and for special glazings.

.5 RSI CURTAINS 12 HRS/DAY ON SOUTH WINDOWS
$.61 \times \frac{.61+.5}{.61+.5 \times 12/24} = .787$

Suggested Values:
.22 for single glazing
.41 for double glazing
.61 for triple glazing

.61 (2A)	.61 (2B)	.787 (2C)	.61 (2D)

WINDOW LOSS COEFFICIENTS (W/C)
Line 1 / Line 2
E.g. (1A) / (2A) = (3A)

4.31 (3A)	7.57 (3B)	17.42 (3C)	1.21 (3D)

TOTAL WINDOW LOSS COEFFICIENT (3A) + (3B) + (3C) + (3D) = 30.51 (4) W/C

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1. ASHRAE window resistance values are appropriate only for estimation of max. load, as extreme weather conditions are assumed. They should not be used in monthly energy calculations. If calculated window resistance is to be used for special glazings, then use .10 for the exterior air film resistance and .12 for the interior air film resistance.

   Resistance values tabulated in the calculation form are for glazing with 12 mm air spaces. For each 6 mm air space deduct .05. Tabulated values are for windows with wood framing taking up 20-25% of the gross window area. If your windows differ significantly then use correction factors for framing types as follows:

   Window metal frame w/o thermal break .79

   Sliding door metal frame w/o thermal break .86

   Wood frame 40% of gross window area 1.12

   If night shutters are used with resistance equal to R_S (.5 to 2.0 are typical values), multiply glass resistance by

$$\frac{R_{GLASS} + R_S}{R_{GLASS} + (R_S \times H/24)}$$

   Where H is number of hours/day without night shutters.

B WALL LOSSES

WALL TYPE Description	A	B	C	D
	E, N+W WALLS	SOUTH WALL		

WALL AREA (m2) Gross wall area minus window area and minus door area. Include wall to attached unheated spaces.

NOTE: Use inside house dimensions to determine wall area with standard construction. For wall with internal mass, measure wall area at midpoint of insulation if possible, otherwise use outside wall dimensions.

153.76 (5A)	29.50 (5B)	(5C)	(5D)

WALL RESISTANCE (Cm2/W)

Calculate by summing resistances of wall layers and air films. Use values given in Thermal Resistane Value tables. (Multiply Imperial R values by .1761 to convert them to metric.)

	A		B		C	D
Exterior Film	.10		.10		.10	.10
Exterior Finish	.074		.074			
Sheathing Matrls (.08) [1]						
Insulation A [2]	2.11	R12	1.41	R8		
Air Space (.17)	.17		.17			
Insulation B [2]	1.87		1.87			
Interior Materials	.026		.026			
Interior Finish (.08) [1]	.12		.12			
Interior Film	.12		.12		.12	.12
SUM=	4.59 (6A)		3.89 (6B)		(6C)	(6D)

WALL LOSS COEFF. W/C	33.50 (7A)	7.58 (7B)	(7C)	(7D)

Line 5/Line 6 E.g. (5A)/(6A)=(7A)

TOTAL WALL LOSS COEFFICIENT (7A) + (7B) + (7C) + (7D) = 41.08 (8) W/C

[1] .08 is the resistance for 9mm plywood or 13mm gypsum board. For other materials see the Thermal Resistance Value tables.

[2] See Note No. 2 regarding adjustment for wood studs in wall.

90 mm BATT EXTRA DENSE 2.47 R

STUD ADJUSTED R = $\frac{1}{.19 + .85/2.47} = 1.87$

---

2. If insulation (+ air space if any) is in stud space, reduce insulation (+ air space) resistance to

$$\frac{1}{.19 + .85/R_{\text{Insulation and air space}}}$$

The above is correct for the standard stud wall.

For a wall with R 2.11 insulation and 400 mm stud spacing, insulation is reduced to R 1.69 (reduction of 20%).

For other stud walls use

$$\frac{1}{F/(\text{stud depth mm} \times 0.0087) + (1-F)/R_{\text{Insulation}}}$$

Where F = fraction of wall area taken up by wood framing or

000097

C CEILING LOSSES

CEILING TYPE	A	B	C	D
Description	ROOF			
CEILING AREA (m2)	92.34 (9A)	(9B)	(9C)	(9D)

CEILING RESISTANCE (Cm2/W) Calculate similar to Wall Resistance.
Note No. 3 applies to ceiling joists also.

	A	B	C	D
Exterior Film	.10	.10	.10	.10
Exterior Finish (.08) SHINGLE	.078			
Exterior Materials BLDG PAPER	.026			
Insulation A	6.79			
Air Space (.15)	.15			
~~Insulation B~~ 10mm PLYWOOD	.087			
Interior Materials 19mm GYPSUM BOARD				
Interior Finish (.08)				
Interior Film	.11	.11	.11	.11
SUM =	7.46 (10A)	(10B)	(10C)	(10D)

CEILING LOSS COEFF. W/C: 12.38 (11A) (11B) (11C) (11D)

Line 9/Line 10
E.g. (9A)(10A)(11A)

GROSS INSULATION RESISTENCE IS R7 (295 mm)
ADJUST 89 mm OF INSULATION FOR WOOD JOISTS (89 mm)
GROSS R OF 89 mm = 2.11 ADJUSTED $R = \frac{1}{38/600/(89\times.0087)+(1-38/600)/2.11} = 1.90$
NET OVERALL R = 7.2.11 + 1.90 = 6.79

TOTAL CEILING LOSS COEFFICIENT (11A) + (11B) + (11C) + (11D) = 12.38 (12) W/C

---

3. If insulation (+ air space if any) is in joist space, reduce insulation (+ air space) resistance to

$$\frac{1}{F/(\text{stud depth mm} \times 0.0087)+(1-F)/R_{\text{Insulation}}}$$

Where F = fraction of wall area taken up by wood framing or joists.

D DOOR LOSSES

DOOR TYPE	A	B	C	D
Description				
DOOR AREA (m2) Include doors to attached unheated spaces.	3.1 (13A)	(13B)	(13C)	(13D)
DOOR RESISTANCE (Cm2/W) Suggested Values: 35mm Wood with metal storm .63; 45mm Steel with urethane core .44	.63 (14A)	(14B)	(14C)	(14D)
DOOR LOSS COEFF. (W/C)	4.92 (15A)	(15B)	(15C)	(15D)

Line 13/Line 14 E.g. (3A)/(14A)=(15A)

TOTAL DOOR LOSS COEFFICIENT (15A) + (15B) + (15C) + (15C) = 4.92 (16) W/C

E SPECIAL PORTIONS OF EXTERIOR SKIN LOSSES

Use for wall plates, joist header areas, overhung floor areas and other wall constructions if substantially different from main wall construction.

SPECIAL PORTION TYPE	A	B	C	D
Description				
SPECIAL PORTION AREA (m2)	(17A)	(17B)	(17C)	(17D)
SPECIAL PORTION RESISTANCE (Cm2/W) Calculate similiar to Wall Resistance.				
Exterior Film	.10	.10	.10	.10
_____				
_____				
_____				
_____				
Interior Film	.12	.12	.12	.12
SUM =	(18A)	(18B)	(18C)	(18D)
LOSS COEFFICIENTS (W/C)	(19A)	(19B)	(19C)	(19D)

Line 17/Line 18 E.g. (17A)/(18A)=(19A)

TOTAL SPECIAL PORTION LOSS COEFFICIENT (19A)+(19B)+(19C)+(19D)= (20) W/C

F INFILTRATION LOSSES

AIR CHANGE RATE Use measured infiltration AIR CHANGES/HR or the following estimated values:

-Older house (pre 1976)	1.0+ AC/hr
-Conventional construction (fossil fuel)	0.5 AC/hr
-Carefully constructed fossil fuel or average electrically heated house	0.3 AC/hr
-Super energy efficient air tight construction	0.05 - 0.1 AC/hr

Use .3 for the last case if there is no forced ventilation with heat exchanger.

0.3 AC/hr (21)

See Note No. 4 regarding minimum ventilation rates and correlation of infiltration to pressurization tests.

HEATED VOLUME Include semi-basement rooms that have walk out doors or large windows. Include 1/2 volume for normal basement spaces.

7.9 × 11.2 × (2.7+2.4+2.55/2

564 m3 (22)

FORCED CONTINUOUS VENTILATION

— m3/h (23)

FORCED VENTILATION HEAT EXCHANGER EFFICIENCY

— % (24)

Assume 70% if actual efficiency not available.

INFILTRATION LOSS COEFFICIENT

$$\left(0.3\ (21) \times 564\ (22) + /\ (23) \times \frac{100 - /\ (24)}{100} \right) \times 0.3345 = 56.6\ (25)\ \text{W/C}$$

4. Internally generated odours and other contaminants require certain minimum ventilation rates. If natural infiltration and forced ventilation are not adequate, then the occupants will resort to artificial added ventilation by opening of windows, operation of toilet and kitchen fans, etc. Therefore a minimum estimated air change of .3 should be assumed, unless continuous forced ventilation is provided. When using air tight construction be careful to provide adequate combustion air for the furnace and the fireplace. Additional mechanical ventilation may be required for the comfort and health of the occupants.

G BASEMENT WALL ABOVE GRADE LOSSES

WALL TYPE	A	B	C	D
Description	8.04 + 9.24			
$2 \times (2 \times 11.7 + 2 \times 8.4) = 8.04$				
ADD EXTRA EXPOSED WALL IN SOUTH ELEVATION $8.4 \times 1.1 = 9.24$				
BASEMENT WALL ABOVE GRADE AREA (m2)	17.28 (26A)	(26B)	(26C)	(26D)

Gross area minus glass in basement wall above grade.

BASEMENT WALL ABOVE GRADE RESISTANCE (Cm2/W) See Note No. 5	A	B	C	D
Exterior Film	.10	.10	.10	.10
Exterior Materials	—			
Insulation	2.64			
Air Space (.17)	—			
Interior Finish (.08)	.08			
Interior Film	.12	.12	.12	.12
SUM=	2.94 (27A)	(27B)	(27C)	(27D)

LOSS COEFFICIENTS (W/C)	A	B	C	D
Line 26/Line 27 E.g. (26A)/(27A)=(28A)	5.88 (28A)	(28B)	(28C)	(28D)

TOTAL WALL ABOVE GRADE LOSS COEFF. (28A)+(28B)+(28C)+(28D)= 5.88 (29) W/C

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5. If insulation (+ air space if any) is in stud space, reduce insulation (+ air space) resistance to

$$\frac{1}{.19 + .85/R_{\text{Insulation and air space}}}$$

The above is correct for the standard stud wall. For a wall with R 2.11 insulation and 400 mm stud spacing, insulation is reduced to R 1.69 (reduction of 20%).

For other stud walls use

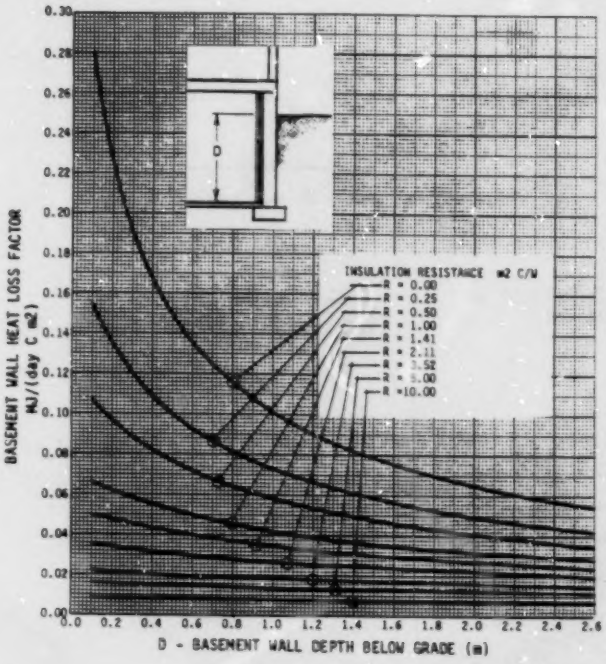
$$\frac{1}{F/(\text{stud depth mm} \times 0.0087) + (1-F)/R_{\text{Insulation}}}$$

Where F = fraction of wall area taken up by wood framing or joists.

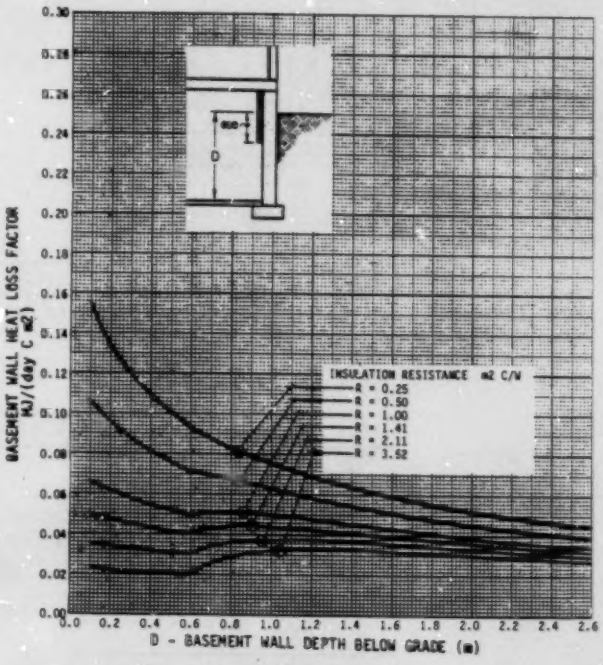
000101

H BASEMENT WALL BELOW GRADE LOSSES

GRAPH No. 1
Use this graph for basement wall losses for cases with full height basement wall insulation and with no basement wall insulation.



GRAPH No. 2
Use this graph for basement wall losses for cases with basement wall insulation extending to 600 mm below grade.



If insulation with a reduced R value is used for the lower portion of the wall or insulation depth is not as shown on the above graphs, use values interpolated between the two graphs.

See Note No. 6

BASEMENT WALL DEPTH BELOW GRADE Average depth $75.78 \div (11.7 + 8.4) \div 2$ = 1.89 m (30)

BASEMENT WALL INSULATION RESISTANCE R-VALUE of insulation only (Zero (0) if no insulation). = 2.64 Cm2/W (31)

BASEMENT WALL HEAT LOSS FACTOR
Insulation depth below grade 1.89 m
Graph No. 1 = 0.02 MJ/dayCm2 (32)

BASEMENT WALL BELOW GRADE AREA
$(11.7 + 8.4) \times 2 \times 2.115 - 9.24$ [EXTRA EXPOSED BSMT IN SOUTH] = 75.78 m2 (33)

BASEMENT WALL MONTHLY LOSS FACTOR

0.02 (32) X 75.78 (33) X 30.3 = 45.92 MJ/month C (34)

---

6. Detached houses have additional basement losses due to corner effects. On the other hand, the sidewalls of the basement of a detached house are generally sheltered to some degree by the neighbouring houses. These two effects largely cancel each other and therefore can be neglected for a house in an average urban setting.

For a house on a corner lot (one side not sheltered) the corner effect can be accounted for by changing 3.6 to 3.2 in the denominator in line 38. For a house exposed on all sides change 3.6 to 2.8.

BASEMENT FLOOR LOSSES

BASEMENT FLOOR AREA
Include vertical area at change in floor level. 98.28 m2 (35)

BASEMENT FLOOR INSULATION RESISTANCE R-VALUE of insulation only (Zero (0) if no insulation). 0 Cm2/W (36)

MEAN ANNUAL TEMPERATURE DIFFERENCE

BASEMENT SPACE TEMPERATURE 20 C MINUS
ANNUAL MEAN OUTSIDE AIR TEMPERATURE 7.4 C = 12.6 C (37)
Obtain from Weather Data Tables
Weather Data Location used TORONTO MET RES

MONTHLY BASEMENT FLOOR LOSS See Note No. 7

$$\frac{98.28\ (35) \times 12.6\ (37) \times 2.62}{0\ (36) + 3.6} = 901 \text{ MJ/month } (38)$$

7. Detached houses have additional basement losses due to corner effects. On the other hand, the sidewalls of the basement of a detached house are generally sheltered to some degree by the neighbouring houses. These two effects largely cancel each other and therefore can be neglected for a house in an average urban setting.

For a house on a corner lot (one side not sheltered) the corner effect can be accounted for by changing 3.6 to 3.2 in the denominator in line 38. For a house exposed on all sides change 3.6 to 2.8.

000103

J ADJUSTMENT FOR ATTACHED UNHEATED SPACES

NOTE: This adjustment can be made for garages, porches, sunrooms and similiar unheated attachments. For an average garage attached to a well insulated wall this adjustment may be neglected. It is important for sunrooms and porches.

CONDUCTANCE HOUSE TO ATTACHED SPACE Include wall, doors windows between HOUSE INTERIOR and the ATTACHED UNHEATED SPACE

5.4 × 2.7 = 14.58
5.28 × 0.25 = 1.32
15.90

15.9	Wall A	/	5.43	Wall R	= 2.93
—	Door A	/		Door R	=
—	Window A	/		Window R	=
—	Area	/		Resistance	=

Total Conductance (House to attached space) 2.93 = 2.9 W/C (39)

CONDUCTANCE ATTACHED SPACE TO OUTDOORS Include all elements between UNHEATED SPACE and OUTDOORS

0.8 × 2.0 = 1.6
5.0 × 2.0 = 10.0
11.6

42.16	Wall A	/	.55	Wall R	= 76.65
11.6	Door A	/	1.06	Door R	= 10.94
—	Window A	/		Window R	=
37.8	Ceiling A	/	.39	Ceiling R	= 96.92
	Area	/		Resistance	=
105.8	Volume	X	0.3345		= 35.40

Total Conductance (Unheated space) 219.91 = 219.9 W/C (40)

NOTE: For a garage, line 40 is in the range of 50 to 250 W/C

See Note No. 8.

ADJUSTMENT FOR ATTACHED UNHEATED SPACES

$$\frac{2.9\ (39)}{1 + 219.9\ (40) / 2.9\ (39)} = .04\ (41)\ \text{W/C}$$

8. Floor (slab on grade) loss for an unheated space can be neglected.

K *** TOTAL ABOVE GRADE LOSS COEFFICIENT ***

Sum all the previously calculated loss coefficients.

The total above grade loss coefficient excludes below grade basement losses and must not be used to size equipment.

Note that the adjustment for unheated spaces must be treated as a negative number.

Window Loss	30.51	4
Wall loss	41.08	8
Ceiling Loss	12.38	12
Door Loss	4.92	16
Special Portions Loss	—	20
Infiltration Loss	56.60	25
Basement Wall Above Grade Loss	5.88	29
SUBTRACT: Adjustment For Unheated Spaces	- .04	41
TOTAL Above Grade Loss Coefficient =	151.33	42 W/C

000105

L *** GROSS MONTHLY HEAT LOSS CALCULATION ***

LOCATION MISSISSAUGA WEATHER DATA LOCATION TORONTO MET RES

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
DEGREE DAY FACTORS Obtain From Weather Data Tables	8.48	23.03	37.89	57.78	66.17	59.04	50.99	30.45	15.63	(50)
MONTHLY ABOVE GRADE LOSS MJ/Month (50) x 151.33 (42)	1283	3485	5734	8744	10014	8935	7716	4608	2365	(51)
MEAN ANNUAL TEMPERATURE DIFFERENCE Enter (37) in each column	12.60	12.60	12.60	12.60	12.60	12.60	12.60	12.60	12.60	(52)
CORRECTION FOR MONTHLY FLUCTUATION See Note No. 9	-10.4	-6.0	0.0	+6.0	+10.4	+12.0	+10.4	+6.0	0.0	(53)
MONTHLY TEMPERATURE DIFFERENCE (52) + (53)	2.20	6.60	12.60	18.60	23.00	24.60	23.00	18.60	12.60	(54)
MONTHLY BASEMENT WALL LOSS (54) x 45.92 (34)	101	303	579	854	1056	1130	1056	854	579	(55)
MONTHLY BASEMENT FLOOR LOSS Enter (38) in each column	901	901	901	901	901	901	901	901	901	(56)
GROSS MONTHLY HEAT LOSS MJ/Month Sum of (51) + (55) + (56)	2285	4689	7214	10499	11971	10966	9673	6363	3845	(60)

9. Monthly fluctuations given in the calculation forms correspond to 12°C amplitude at 5 cm below grade. This is approximately correct for all Ontario locations with such measured data. For locations with known amplitudes that differ substantially from 12°C, multiply each number in line 53 by "amplitude"/12.

M *** HEATING ENERGY REQUIREMENT CALCULATION ***

INTERNAL GAINS (MJ/month) Average Occupancy during 24 hours (see Note 10) 1.5 Persons x 200 + 1300 = 1600 (61)

ROOM THERMOSTAT SETTING (deg C) Suggested Setting : 20 C 20 (62)

NET INTERNAL GAINS (MJ/month) (Can be negative) 1600 (61) - 151.33 (42) x (20 (62) - 18) x 2.62 = 807 (63)

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
GROSS MONTHLY HEAT LOSS (MJ/month) Enter Numbers of Line (60)	2285	4689	7214	10499	11971	10966	9673	6363	3845	(64)
MONTHLY NET INTERNAL GAINS Enter Line (63) in each column	807	807	807	807	807	807	807	807	807	(65)
NET MONTHLY HEAT LOSS (MJ/mo) (64) - (65) Enter zero (0) if negative	1478	3882	6407	9692	11164	10159	8866	5556	3038	(66)
MONTHLY SOLAR GAINS RATE (SOUTH) MJ/m2/month from weather tables	189	191	121	146	200	236	234	190	153	(67)
GLAZING TYPE FACTOR 1.1 single glazing (1.0 double glazing) .91 triple glazing .83 quadruple glzg	.91	.91	.91	.91	.91	.91	.91	.91	.91	(68)
OVERHANG OR OBSTRUCTION SHADING FACTOR Use 1.0 if no shading. See Note 11	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	(69)
CLEAR GLASS AREA (SOUTH) Exclude framing Use 75% of south window area in heat loss calcs, or measured clear area	9.95	9.95	9.95	9.95	9.95	9.95	9.95	9.95	9.95	(70)
MONTHLY SOLAR GAINS (67) x (68) x (69) x (70) MJ/Month See Notes 12 & 13 (Form L-13)	1711	1729	1096	1322	1811	2137	2119	1720	1385	(71)
SOLAR/LOAD RATIO (71) / (66)	1.16	0.45	0.17	0.14	0.16	0.21	0.24	0.31	0.46	(72)
MONTHLY SOLAR UTILIZATION EFFICIENCY See Note No. 14 (On Form L-13)	0.64	0.90	0.98	0.99	0.98	0.97	0.96	0.94	0.89	(73)
MONTHLY PASSIVE HEAT (71) x (73) MJ/month	1095	1556	1074	1309	1775	2073	2034	1617	1233	(74)
MONTHLY AUXILIARY HEAT (66) - (74) MJ/month	383	2326	5333	8383	9389	8086	6832	3939	1805	(75)

ANNUAL AUXILIARY HEAT Add all numbers in (75): 46476 MJ/Year

BASE CASE CALCULATION
-NO SHADING, SOUTH GLASS SOLAR GAINS ONLY

10. Internal gains rate due to lighting, appliances, hot water tank losses, is estimated at 1300 MJ/month for a house with 100-150 m^2 floor area. A house with twice as much floor area may have 50% higher internal gains. Use measured internal gains where available. Measured electricity consumption may be used after deductions for heat exhausted by clothes dryers and kitchen exhaust fans as well as outdoor electricity use.

11. For a discussion of shading by overhangs, protruding house walls, trees and other obstructions see 3.6 Shading Effects. See also 3.7 Effects of Off-True-South Orientation.

12. In a more refined calculation, solar gains through other than south glazing may be considered. In an urban setting, side walls are generally shaded by neighbouring housing. Therefore glass only in the front wall and the rear wall needs to be considered. Solar gains through glazing with other than south orientation is calculated in the same manner as for south glazing. For housing with poorly insulated ceilings or walls, substantial solar gains take place through such walls or ceilings. The sum of solar gains through glass, walls and ceiling for each month is entered on Line 71.

Solar gain through ceiling can be estimated by means of the following formula:

$$S_c = (a-.4) \times S_i \times 0.08/(R+3)$$

where: S_c - solar gain rate through ceiling in $MJ/m^2/month$

a - solar absorptivity of roof
.8 for dark surfaces
.6 for medium surfaces
.4 for light surfaces

S_i - incident solar on horizontal surface in $MJ/m^2/month$

R - overall resistance of ceiling

0.08 - average resistance of air film during hours of substantial sunshine (obtained from extensive hourly computer simulations)

.4 - accounts for the effects of infrared sky radiation

3 - the ventilated attic effect

The net useful gain through the opaque south wall is:

$$S_w = S_s \times 0.06 / R$$

Where: S_s - solar gain for double glazed south windows, $MJ/m^2/month$

R - overall resistance of wall

Use of the window solar gain in place of the incident solar, accounts for the solar absorptivity of a medium coloured wall. Increase solar window gains by 30% for dark walls and decrease by 30% for light walls. The magnitude of the infrared sky radiation loss is such that it approximately balances the useful diffuse solar gains on the north wall and therefore both can be omitted.

000107

M *** HEATING ENERGY REQUIREMENT CALCULATION ***

INTERNAL GAINS (MJ/month) Average Occupancy during 24 hours (see Note 10) 1.5 Persons x 200 + 1300 = 1600 (61)

ROOM THERMOSTAT SETTING (deg C) Suggested Setting : 20 C 20 (62)

NET INTERNAL GAINS (MJ/month) (Can be negative) 1600 (61) - 151[illegible] (42) x (20 (62) - 18) x 2.62 = 807 (63)

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
GROSS MONTHLY HEAT LOSS (MJ/month) Enter Numbers of Line (60)	2285	4689	7214	10499	11971	10966	9673	6363	3845	(64)
MONTHLY NET INTERNAL GAINS Enter Line (63) in each column	807	807	807	807	807	807	807	807	807	(65)
NET MONTHLY HEAT LOSS (MJ/mo) (64) - (65) Enter zero (0) if negative	1478	3882	6407	9692	11164	10159	8866	5556	3038	(66)
MONTHLY SOLAR GAINS RATE (SOUTH) MJ/m2/month from weather tables										(67)
GLAZING TYPE FACTOR 1.1 single glazing (1.0 double glazing) .91 triple glazing .83 quadruple glzg										(68)
OVERHANG OR OBSTRUCTION SHADING FACTOR Use 1.0 if no shading. See Note 11										(69)
CLEAR GLASS AREA (SOUTH) Exclude framing Use 75% of south window area in heat loss calcs, or measured clear area										(70)
MONTHLY SOLAR GAINS (67) x (68) x (69) x (70) MJ/Month See Notes 12 & 13 (Form L-13)	2045	1992	1253	1494	2048	2440	2496	2123	1826	(71)
SOLAR/LOAD RATIO (71) / (66)	1.38	0.51	0.20	0.15	0.18	0.24	0.28	0.38	0.60	(72)
MONTHLY SOLAR UTILIZATION EFFICIENCY See Note No. 14 (On Form L-13)	0.57	0.87	0.97	0.98	0.98	0.96	0.95	0.92	0.84	(73)
MONTHLY PASSIVE HEAT (71) x (73) MJ/month	1166	1733	1215	1464	2007	2342	2371	1953	1534	(74)
MONTHLY AUXILIARY HEAT (66) - (74) MJ/month	312	2149	5192	8228	9157	7817	6495	3603	1504	(75)

ANNUAL AUXILIARY HEAT Add all numbers in (75): 44457 MJ/Year

SEE ATTACHED CALCULATION OF SOLAR GAINS

BASE CASE PLUS SOLAR GAINS THROUGH NORTH WINDOWS, SOUTH WALL AND ROOF

10. Internal gains rate due to lighting, appliances, hot water tank losses, is estimated at 1300 MJ/month for a house with 100-150 m^2 floor area. A house with twice as much floor area may have 50% higher internal gains. Use measured internal gains where available. Measured electricity consumption may be used after deductions for heat exhausted by clothes dryers and kitchen exhaust fans as well as outdoor electricity use.

11. For a discussion of shading by overhangs, protruding house walls, trees and other obstructions see 3.6 Shading Effects. See also 3.7 Effects of Off-True-South Orientation.

12. In a more refined calculation, solar gains through other than south glazing may be considered. In an urban setting, side walls are generally shaded by neighbouring housing. Therefore glass only in the front wall and the rear wall needs to be considered. Solar gains through glazing with other than south orientation is calculated in the same manner as for south glazing. For housing with poorly insulated ceilings or walls, substantial solar gains take place through such walls or ceilings. The sum of solar gains through glass, walls and ceiling for each month is entered on Line 71.

Solar gain through ceiling can be estimated by means of the following formula:

$$S_c = (a-.4) \times S_i \times 0.08/ (R+3)$$

where: S_c - solar gain rate through ceiling in $MJ/m^2/month$

a - solar absorptivity of roof
.8 for dark surfaces
.6 for medium surfaces
.4 for light surfaces

S_i - incident solar on horizontal surface in $MJ/m^2/month$

R - overall resistance of ceiling

0.08 - average resistance of air film during hours of substantial sunshine (obtained from extensive hourly computer simulations)

.4 - accounts for the effects of infrared sky radiation

3 - the ventilated attic effect

The net useful gain through the opaque south wall is:

$$S_w = S_s \times 0.06 / R$$

Where: S_s - solar gain for double glazed south windows, $MJ/m^2/month$

R - overall resistance of wall

Use of the window solar gain in place of the incident solar, accounts for the solar absorptivity of a medium coloured wall. Increase solar window gains by 30% for dark walls and decrease by 30% for light walls. The magnitude of the infrared sky radiation loss is such that it approximately balances the useful diffuse solar gains on the north wall and therefore both can be omitted.

SUNSET, MISSISSAUGA

MONTHLY SOLAR GAINS INCLUDING NORTH GLASS, WALLS AND CEILING (NO OVERHANGS)

SOUTH GLASS FACTOR = AREA*GLAZING TYPE FACTOR = 9.95 * .91 = 9.05
NORTH GLASS FACTOR = AREA*GLAZING TYPE FACTOR = 2 * .91 = 1.82
SOUTH WALL FACTOR = AREA*.06/R = 29.5 * .06 / 3.89 = 0.46
CEILING FACTOR = AREA*(ABSORPTIVITY - .4)*.08/(R+3) =
= 92.34 * (.8 - .4) * .08 / (7.46 + 3) = 0.28

	Sep				Oct				Nov			
S Glass	189	*	9.05	= 1,710	191	*	9.05	= 1,729	121	*	9.05	= 1,095
N Glass	71	*	1.82	= 129	52	*	1.82	= 95	34	*	1.82	= 62
S Wall	189	*	0.46	= 87	191	*	0.46	= 88	121	*	0.46	= 56
Ceiling	424	*	0.28	= 119	284	*	0.28	= 80	143	*	0.28	= 40
				2,045				1,992				1,253

	Dec				Jan				Feb			
S Glass	146	*	9.05	= 1,321	200	*	9.05	= 1,810	236	*	9.05	= 2,136
N Glass	37	*	1.82	= 67	51	*	1.82	= 93	66	*	1.82	= 120
S Wall	146	*	0.46	= 67	200	*	0.46	= 92	236	*	0.46	= 109
Ceiling	138	*	0.28	= 39	189	*	0.28	= 53	269	*	0.28	= 75
				1,494				2,048				2,440

	Mar				Apr				May			
S Glass	234	*	9.05	= 2,118	190	*	9.05	= 1,720	153	*	9.05	= 1,385
N Glass	86	*	1.82	= 157	91	*	1.82	= 166	112	*	1.82	= 204
S Wall	234	*	0.46	= 108	190	*	0.46	= 87	153	*	0.46	= 70
Ceiling	405	*	0.28	= 113	536	*	0.28	= 150	597	*	0.28	= 167
				2,496				2,123				1,826

000109

M *** HEATING ENERGY REQUIREMENT CALCULATION ***

INTERNAL GAINS (MJ/month) Average Occupancy during 24 hours (see Note 10) 1.5 Persons x 200 + 1300 = 1600 (61)

ROOM THERMOSTAT SETTING (deg C) Suggested Setting : 20 C 20 (62)

NET INTERNAL GAINS (MJ/month) (Can be negative) 1600 (61) - 15/33 (42) x (20 (62) - 18) x 2.62 = 807 (63)

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
GROSS MONTHLY HEAT LOSS (MJ/month) Enter Numbers of Line (50)	2285	4689	7214	10499	11971	10966	9673	6363	3845	(64)
MONTHLY NET INTERNAL GAINS Enter Line (63) in each column	807	807	807	807	807	807	807	807	807	(65)
NET MONTHLY HEAT LOSS (MJ/mo) (64) - (65) Enter zero (0) if negative	1478	3882	6407	9692	11164	10159	8866	5556	3038	(66)
MONTHLY SOLAR GAINS RATE (SOUTH) MJ/m2/month from weather tables										(67)
GLAZING TYPE FACTOR 1.1 single glazing (1.0 double glazing) .91 triple glazing .83 quadruple glzg										(68)
OVERHANG OR OBSTRUCTION SHADING FACTOR Use 1.0 if no shading. See Note 11										(69)
CLEAR GLASS AREA (SOUTH) Exclude framing Use 75% of south window area in heat loss calcs, or measured clear area										(70)
	SEE ATTACHED CALCULATION OF SOLAR GAINS									
MONTHLY SOLAR GAINS (67) x (68) x (69) x (70) MJ/Month See Notes 12 & 13 (Form L-13)	1824	1835	1190	1418	1943	2769	2274	1881	1635	(71)
SOLAR LOAD RATIO (71) / (66)	1.23	0.47	0.19	0.15	0.17	0.22	0.26	0.34	0.54	(72)
MONTHLY SOLAR UTILIZATION EFFICIENCY See Note No. 14 (On Form L-13)	0.62	0.89	0.98	0.98	0.98	0.97	0.96	0.93	0.86	(73)
MONTHLY PASSIVE HEAT (71) x (73) MJ/month	1131	1633	1166	1390	1904	2201	2183	1749	1406	(74)
MONTHLY AUXILIARY HEAT (66) - (74) MJ/month	347	2249	5241	8302	9260	7958	6683	3807	1632	(75)

ANNUAL AUXILIARY HEAT Add all numbers in (75): 45479 MJ/Year

BASE CASE WITH OVERHANG SHADING PLUS SOLAR GAINS THROUGH NORTH GLASS, SOUTH WALL AND ROOF.

10. Internal gains rate due to lighting, appliances, hot water tank losses, is estimated at 1300 MJ/month for a house with 100-150 m^2 floor area. A house with twice as much floor area may have 50% higher internal gains. Use measured internal gains where available. Measured electricity consumption may be used after deductions for heat exhausted by clothes dryers and kitchen exhaust fans as well as outdoor electricity use.

11. For a discussion of shading by overhangs, protruding house walls, trees and other obstructions see 3.6 Shading Effects. See also 3.7 Effects of Off-True-South Orientation.

12. In a more refined calculation, solar gains through other than south glazing may be considered. In an urban setting, side walls are generally shaded by neighbouring housing. Therefore glass only in the front wall and the rear wall needs to be considered. Solar gains through glazing with other than south orientation is calculated in the same manner as for south glazing. For housing with poorly insulated ceilings or walls, substantial solar gains take place through such walls or ceilings. The sum of solar gains through glass, walls and ceiling for each month is entered on Line 71.

Solar gain through ceiling can be estimated by means of the following formula:

$$S_c = (a-.4) \times S_i \times 0.08/(R+3)$$

where: S_c - solar gain rate through ceiling in MJ/m^2/month

a - solar absorptivity of roof
.8 for dark surfaces
.6 for medium surfaces
.4 for light surfaces

S_i - incident solar on horizontal surface in MJ/m^2/month

R - overall resistance of ceiling

0.08 - average resistance of air film during hours of substantial sunshine (obtained from extensive hourly computer simulations)

.4 - accounts for the effects of infrared sky radiation

3 - the ventilated attic effect

The net useful gain through the opaque south wall is:

$$S_w = S_s \times 0.06 / R$$

Where: S_s - solar gain for double glazed south windows, MJ/m^2/month

R - overall resistance of wall

Use of the window solar gain in place of the incident solar, accounts for the solar absorptivity of a medium coloured wall. Increase solar window gains by 30% for dark walls and decrease by 30% for light walls. The magnitude of the infrared sky radiation loss is such that it approximately balances the useful diffuse solar gains on the north wall and therefore both can be omitted.

SUNSET, MISSISSAUGA

MONTHLY SOLAR GAINS INCLUDING NORTH GLASS, WALLS, CEILING AND OVERHANG SHADING

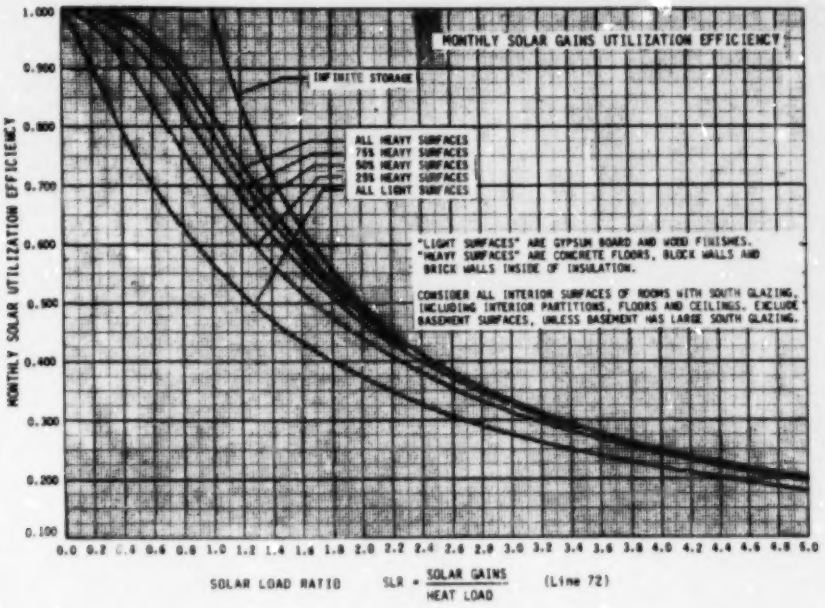
UNSHADED SOUTH GLASS FACTOR = AREA*GLAZING TYPE FACTOR = 7.21 * .91 = 6.56
SHADED SOUTH GLASS FACTOR = AREA*GLAZING TYPE FACTOR = 2.74 * .91 = 2.49
NORTH GLASS FACTOR = AREA*GLAZING TYPE FACTOR = 2 * .91 = 1.82
SOUTH WALL FACTOR = AREA*.06/R = 29.5 * .06 / 3.89 = 0.46
CEILING FACTOR = AREA*(ABSORPTIVITY - .4)*.08/(R+3) =
= 92.34 * (.8 - .4) * .08 / (7.46 + 3) = 0.28

	Sep		Oct		Nov	
UnshSGl	189 * 6.56 =	1,240	191 * 6.56 =	1,253	121 * 6.56 =	794
ShSGlas	189*2.49*0.53 =	249	191*2.49*0.67 =	319	121*2.49*0.79 =	238
N Glass	71 * 1.82 =	129	52 * 1.82 =	95	34 * 1.82 =	62
S Wall	189 * 0.46 =	87	191 * 0.46 =	88	121 * 0.46 =	56
Ceiling	424 * 0.28 =	119	284 * 0.28 =	80	143 * 0.28 =	40
		1,824		1,835		1,190

	Dec		Jan		Feb	
UnshSGl	146 * 6.56 =	958	200 * 6.56 =	1,312	236 * 6.56 =	1,548
ShSGlas	146*2.49*0.79 =	287	200*2.49*0.79 =	393	236*2.49*0.71 =	417
N Glass	37 * 1.82 =	67	51 * 1.82 =	93	66 * 1.82 =	120
S Wall	146 * 0.46 =	67	200 * 0.46 =	92	236 * 0.46 =	109
Ceiling	138 * 0.28 =	39	189 * 0.28 =	53	269 * 0.28 =	75
		1,418		1,943		2,269

	Mar		Apr		May	
UnshSGl	234 * 6.56 =	1,535	190 * 6.56 =	1,246	153 * 6.56 =	1,004
ShSGlas	234*2.49*0.62 =	361	190*2.49*0.49 =	232	153*2.49*0.50 =	190
N Glass	86 * 1.82 =	157	91 * 1.82 =	166	112 * 1.82 =	204
S Wall	234 * 0.46 =	108	190 * 0.46 =	87	153 * 0.46 =	70
Ceiling	405 * 0.28 =	113	536 * 0.28 =	150	597 * 0.28 =	167
		2,274		1,881		1,635

000111


MONTHLY SOLAR GAINS UTILIZATION EFFICIENCY
INFINITE STORAGE
ALL HEAVY SURFACES
75% HEAVY SURFACES
50% HEAVY SURFACES
25% HEAVY SURFACES
ALL LIGHT SURFACES
"LIGHT SURFACES" ARE GYPSUM BOARD AND WOOD FINISHES.
"HEAVY SURFACES" ARE CONCRETE FLOORS, BLOCK WALLS AND BRICK WALLS INSIDE OF INSULATION.
CONSIDER ALL INTERIOR SURFACES OF ROOMS WITH SOUTH GLAZING, INCLUDING INTERIOR PARTITIONS, FLOORS AND CEILINGS. EXCLUDE BASEMENT SURFACES, UNLESS BASEMENT HAS LARGE SOUTH GLAZING.
MONTHLY SOLAR UTILIZATION EFFICIENCY
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8 5.0
SOLAR LOAD RATIO
SLR = SOLAR GAINS / HEAT LOAD (Line 72)

13. A portion of the solar gains in sun porches, glazed vestibules and attached greenhouses enters the house and constitutes a useful solar gain. In essence the solar energy goes back to the outdoors through the exterior skin of the porch as well as through the house and its skin. The split of the energy flow can be calculated using the principle of superimposition and the appropriate series/parallel resistances.

Approximately the useful house gain is calculated as follows:

$$G_h = G_s \frac{\boxed{39} - C}{\boxed{39} + \boxed{40} - C}$$

where G_h = useful monthly house gain

G_s = monthly solar gain to sunporch, vestibule or greenhouse

C = small correction for the exact calculation (may be neglected)

$$C = \frac{\boxed{39} \times \boxed{39}}{\boxed{42} \times \boxed{41}}$$

The above calculation can be used for solar greenhouses communicating with the house through a mass wall without insulation. Mass walls can be thought of as offering little resistance to intermittent solar gain energy flow. Solar gains should be considered to be entering the mass wall directly. Therefore conductances for solar gains to the indoors and to the outdoors should be recalculated accordingly.

14. If the SLR value is beyond the range of the chart (greater than 5) then all of the heating requirement will be satisfied by the solar energy. Enter numbers from line No. 66 into line No. 74.

A more exact way than indicated in Part I, section 1.6.1, to deal with a variety of surfaces is to use the Average Solar Absorption Factor (Line No. 85) determined in the Heat Storage Capacity calculation that may be found elsewhere in the present calculation forms. The graphs in the Monthly Solar Utilization Efficiency figure were derived for the following Average Solar Absorption Factors:

% Heavy Surfaces	Average Solar Absorption Factor
0	0.23
25	0.38
50	0.54
75	0.70
100	0.86

Graphs are for a 5 deg. C. temperature swing during sunny winter days. Higher or lower temperature swings have a minor effect. As an illustration of this effect the following efficiencies are determined for SLR = 0.5:

% Heavy Surfaces	3 deg. Swing	5 deg. Swing	7 deg. Swing
0	.71	.75	.77
25	.85	.88	.89
50	.92	.93	.94
75	.95	.96	.97
100	.97	.98	.98

000112

*** HEAT STORAGE CAPACITY CALCULATION ***

For Room(s) with South Glazing

B SOLAR STORAGE

	Floor	----- Walls and Ceiling ------			Sum for all SURFACES
	FLOOR	STO WALL + CEILING	BRICK WALL		
Area m2 (See Note 1)	18.2 (80A)	+ 44.7 (80B)	+ 12.4 (80C)	+ (80D)	= 75.3 (80)
Material	CONCRETE	GYPSUM BD	BRICK		
Closest Graph Material	SOLID CONCRETE	GYPSUM BOARD	SOLID CONCRETE		
Thickness mm	125	19	100		
Carpet (yes/no)	YES	NO	NO		
Solar Storage Factor See Note No. 2	.44 (81A)	.265 (81B)	.86 (81C)	(81D)	(81)
Multiply Factors by Appropiate Areas Line 80 x Line 81 E.g. (80A) x (81A) = (82A)	8.0 (82A)	+ 11.8 (82B)	+ 10.7 (82C)	+ (82D)	= 30.5 (82)
Swing Storage Factor See Note No. 3	16 (83A)	12.7 (83B)	29 (83C)	(83D)	(83)
Multiply Factors by Appropiate Areas Line 80 x Line 83 E.g. (80A) x (83A) = (84A)	291 (84A)	+ 568 (84B)	+ 360 (84C)	+ (84D)	= 1219 (84)

Average Solar Absorption Factor See Note No. 4

$$\frac{0.8\ Y \times .44\ (81A) + 30.5\ (82) / 75.3\ (80)}{2} = .379\ (85)$$

Y=1.0 if no carpet
Y=0.8 if there is a carpet

Clear South Glass Area m2: 3.83 (86)

Sunny winter day solar gains to time of swing maximum: 12700 Z x 3.83 (86) = 48641 kJ (87)

Z = 15 400 kJ/m2 for single glazing
Z = 14 000 kJ/m2 for double glazing
Z = 12 700 kJ/m2 for triple glazing
Z = 11 600 kJ/m2 for quadruple glazing

TOTAL SOLAR STORAGE (Without Temperature Swing): .379 (85) x 48641 (87) = 18435 kJ (88)

---

1. There are four columns provided in the calculation forms for surfaces of different materials. Floor has to be treated separately. Walls, partitions and ceilings of the same material can be lumped together. In the case of an interior brick or block partition between two rooms, include the full thickness of such masonry if it communicates with a room without significant south glazing. Include half thickness of such masonry if it is shared with another room with south glazing.

   Assume that doors are open in a residence during the day. Doorways and archways to a room with significant south glazing should be omitted from the calculation. Such openings to rooms without significant south glazing are good absorbers of heat and are to be included in the area of such partition. For higher accuracy lump such areas with the surfaces of "heavy" material.

2. Read Solar Storage Factor from graph (Form HS1) for the appropriate material. Note separate graphs for surfaces covered with carpets. For Aspenite chipboard and Platewood particleboard use "hardwood" graphs, "softwood" for plywood. Use solid concrete graph for brick.

3. Read Swing Storage Factor from graph (Form HS1) for the appropriate material. Note separate graphs for surfaces covered with carpets.

4. Floor Storage Factor (Box 81A) is treated differently from the other storage factors at it represents the target area for the solar image of the window during most of a sunny winter day.

C AIR SWING STORAGE

Design Temperature Swing
Use 3 to 7 deg C (5 deg is suggested) — 5 C (89)

Floor to Basement Storage
Include only if basement has no significant south glazing. If there is a carpet deduct 30%.
12.7 m2 x 5 (89) x16 = 1016 kJ (90)
18.2 X .7 = 12.7 m² CARPET EFFECT

Partitions to Adjacent Rooms Storage
Include only those to rooms that do not have significant south glazing.
10.94 m2 x 5 (89) x16 = 875 kJ (91)

Ceiling to Upper Floor Storage
Applies only to lower floor south spaces that communicate with upper floor spaces without south glazing. If there is a carpet on the upper floor deduct 30%.
m2 x (89) x16 = kJ (92)

Open Doors and Stairwells to spaces without significant south glazing. See Note No. 5
1.0 m2 x 5 (89) x200 = 1000 kJ (93)

Furniture Allowance
See Note No. 6
floor area 18.2 m2 x 5 (89) x12 = 1092 kJ (94)

Furnace Circulation Allowance. (NIL for electrical baseboard heating systems) See Note No. 7
floor area 18.2 m2 x 5 (89) x15 = 1365 kJ (95)

Storage in Floor, Wall and Ceiling Materials
1219 (84) x 5 (89) = 6095 kJ (96)

TOTAL Air Temperature Swing Storage
Sum of Lines (90), (91), (92), (93), (94), (95), (96)
= 11443 kJ (97)

TOTAL SOLAR AND AIR SWING STORAGE
18435 (88) + 11443 (97) = 29878 KJ (98)

5. Area of door or stairwell used in this calculation should not exceed 10% of the area of the connecting wall for doors or connecting floor/ceiling for stairwells. If the actual area is greater than 10% then use 10%. Assume that all doors are open in a residence during the day.

6. The furniture allowance includes for a typical weight of furniture per square metre of floor area, represented by storage of 12 KJ/C/m^2.

7. Storage factor of 15 is based on a furnace circulation rate of 20m^3/h sq. m. of floor area. Adjust factor proportionately if extra high air circulation is used. If return grilles are placed near ceiling, then increase the furnace circulation allowance by 50%. If a separate basement destratification fan with separate ductwork from a massive basement to grilles near ceiling of the southern rooms is installed, then add the following extra storage:

Room Air Floor Rate (m^3/h) x Design Temperature Swing x 1.2 (kJ)

Factor of 1.2 in the above formula is approximate for average coupling of air to the basement mass. For very good coupling, such as in properly designed rock beds, this factor can be as high as 3.0.

000114

D REQUIRED STORAGE

Internal Gains
See Note No. 8 — 1500 kJ (99)

TOTAL GAINS — 48641 (87) + 1500 (99) = 50141 kJ (100)

Volume of South Space Being Considered — 44.23 m3 (101)

Losses to Outdoors
See Note No. 9

Windows	5.25 Area m2	/	.61 R Cm2/W	= 8.61 W/C (102)
Doors	Area m2	/	R Cm2/W	= W/C (103)
Net Wall A	2.77 Area m2	/	3.89 R Cm2/W	= .71 W/C (104)
Net Wall B	13.4 Area m2	/	4.59 R Cm2/W	= 2.92 W/C (105)
Net Wall C	Area m2	/	R Cm2/W	= W/C (106)
Ceiling	Area m2	/	R Cm2/W	= W/C (107)

Infiltration: $\frac{0.5 \times 56.6\ (25) \times 44.23\ (101)}{564\ (22)}$ = 2.22 W/C (108)

Sum of Heat Loss Factors
Add Lines (102) (103) (104) (105) (106) (107) and (108) — 14.46 W/C (109)

TOTAL LOSSES — 14.46 (109) x (90 + 8.06 x 66.17 DDF) = 9013 kJ (110)

DDF - Degree Day Factor for January
See Note No. 10

REQUIRED STORAGE — 50141 (100) - 9013 (110) = 41128 kJ (111)

If Required Storage (111) is less than Total Solar and Air Swing Storage (98), then adequate storage is available.

If not, then the actual temperature swing will be greater than the Design Temperature Swing 89 , indicating that additional storage is required.

NOTE: Rather than comparing the Stored Heat vs Required Storage, the Estimated Temperature Swing can be calculated as follows:

Temperature Swing = 5 (89) x $\left(\frac{41128\ (111) - 18435\ (88)}{11443\ (97)}\right)$ = 9.92 C

---

8. Enter internal gains estimated for the period of 8 a.m. to 2 p.m. for the specific space or spaces being considered. The following values are suggested.

Living room	-	1500 kJ
Family room	-	1500 kJ
Dining room	-	1500 kJ
Kitchen	-	3000 kJ
Bedroom	-	NIL

9. Consider only the losses from the south facing space or spaces being considered in the storage calculation, not the whole house. Use component resistance values from the Heat Loss Calculation. For windows with shutters assume the shutters are open.

10. The factors of 90 and 8.06 convert degree day factor to a temperature difference, increase space temperature above the degree day base of 18C and convert Wh to kJ.

Degree day factor (DDF) for January can be found in the Weather Data Tables for a specific location.

000115

APPENDIX F: FURTHER READING

Builders' Guide to Energy Efficiency in New Housing
Housing and Urban Development Association of Canada, and Ontario Ministry of Energy

Residential Passive Solar Design and Construction Project Reports
Energy Mines and Resources Canada, Ontario Ministry of Energy, Housing and Urban Development Association of Canada

The Conservation of Energy in Housing
Canada Mortgage and Housing Corporation

Energy Efficient Housing - A Prairie Approach
Alberta Energy and Natural Resources, Saskatchewan Mineral Resources, Manitoba Department of Energy and Mines

Double E Home Program, Technical Guidelines for New Homes
Canadian Electrical Association

Condensation in the Home; Where, Why, and What To Do About It
Canada Mortgage and Housing Corporation

Energy Conservation in New Small Residential Buildings
Canada Mortgage and Housing Corporation

Residential Passive Solar Heating: Review and Development of Design Aids
Ontario Ministry of Energy

Low Energy Passive Solar Demonstration Project
Ontario Ministry of Energy, Housing and Urban Development Association of Canada

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